S_NAr-based DOS Strategies for the Facile Synthesis of Benzofused Sultam Libraries

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Submitted to the Department of Chemistry and the Faculty of the Graduate School of the University of Kansas in partial fulfillment of the requirements for the degree of Doctor of Philosophy

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The overarching goal of this dissertation is the development of strategies and methodologies aimed at the diversity-oriented synthesis of benzofused sultam libraries utilizing the ability of α-fluorobenzenesulfonamides to undergo nucleophilic aromatic substitution (S_NAr). The development of a new method for the synthesis of benzofused sultams via a strategy termed as complementary ambiphile pairing (CAP) is described. This approach entails the complementary pairing of two ambiphilic synthons, α-fluorobenzenesulfonamides and ortho-quinone methides (*o*-QM's) in a formal one-pot, hetero [4+4] approach to afford the novel dibenzo[*b*,*g*][1,4,5]oxathiazocine-5,5-dioxide ring system. An orthogonal reaction pairing strategy based on the ability of α-fluorobenzenesulfonamides to undergo facile nucleophilic aromatic substitution to generate diverse polycyclic benzofused sultams is also reported. Several reaction pathways that are orthogonal to the S_NAr reaction are paired with the S_NAr pathway, including intramolecular Mitsunobu alkylation, epoxide ring opening and [3+2] azide-alkyne Huisgen cycloadditions to generate an array of diverse benzofused sultams. Lastly, a strategy termed "click, cyclize, click" to afford an array of benzofused sultams is described. This approach entails amino alcohol sulfonylation (Click) utilizing α-fluorobenzenesulfonyl chlorides and subsequent intramolecular S_NAr *O*-arylation to afford benzofused sultams containing 2º sulfonamide N-H's. A number of reaction pathways including Mitsunobu alkylation, conventional alkylations, acylations and S_NAr additions are subsequently utilized in diversification of the core scaffold. The utilization of ROMP-derived oligomeric triphenylphosphine (OTPP) in the production of a prototype benzyl benzothiaoxazepine-1,1-dioxide library is also described.

Dedicated

To My Beloved Wife,

Chamalie Wathsala Samarakoon

The Love of My Life.

And My Pillar of Strength.

Dedicated To

My Beloved Parents

Tikiri Banda Samarakoon

&

Devika Kulasobani Samarakoon

For Your Love and Dedication.

You inspired me.

Acknowledgment

It is with great pleasure that I thank all those who had a part in the successful completion of my dissertation.

I dedicate this dissertation to my wife Chamalie, the great love of my life and my source of strength. I could not have asked for a more wonderful person to share my life with and I am thankful for you every second of my life. Your love, support, patience and energy sustained me throughout this great experience. Thank you and I love you.

My parents worked hard and made so many sacrifices all their lives on my behalf. They are the source of my very being, inspired me all my life and continue to do so. It is my great honor and pleasure to dedicate this dissertation to you both. To express gratitude to you both is impossible, but I say Thank You appachchi and ammi.

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Thiwanka B. Samarakoon

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Abbreviations

Ac	acetyl
aq	aqueous
Bn	benzyl
COSY	correlation spectroscopy
C	carbon
Cs_2CO_3	cesium carbonate
Cl	chlorine
DBU	1.8-diazabicyclo[5.4.0]undec-7-ene
DCM	dichloromethane
DCE	dichloroethane
DEPT	distortionless enhancement by polarization transfer
DIBAl-H	diisobutylaluminum hydride
DIPEA	*N*,*N*-diisopropylethylamine
DIAD	diisopropyl azodicarboxylate
DMAP	4-(dimethylamino)pyridine
DME	1,2-dimethoxyethane
DMF	*N*,*N*-dimethylformamide
DMP	Dess-Martin Periodinane
DMAP	4-*(*dimethylamino)pyridine
DMSO	dimethyl sulfoxide
DNA	deoxyribonucleic acid
DOS	diversity-oriented synthesis
E^+	electrophile
Equiv.	equivalent
Et	ethyl
Et_3N	triethylamine
EtOAc	ethyl acetate

FAB	fast atom bombardment
GC	gas chromatography
HCl	hydrochloric acid
HMQC	heteronuclear multiple quantum coherence
HPLC	high performance liquid chromatography
HRMS	high resolution mass spectrometry
hr	hour
HIV	Human immunodeficiency virus
Hz	hertz
^{i}Bu	isobutyl
IR	infrared radiation
^{i}Pr	isopropyl
KHMDS	potassium bis(trimethylsilyl)amide
K_2CO_3	potassium carbonate
OMe	methoxy
*m*W	microwave
Me	methyl
Mo	molybdenum
MsCl	methanesulfonyl chloride
MMP	matrix metalloproteinase
mmol	millimole(s)
mL	Milliliter(s)
N-	nitrogen-
NBS	*N*-bromosuccinimide
NaH	sodium hydride
Nuc	nucleophile
^{n}Bu	*n*-Butyl
NMR	nuclear magnetic resonance
O	oxygen

[O]	oxidation
Ph	phenyl
Pd	palladium
PMB	*p*-methoxybenyzl
PPTS	piridimiun paratoluenesulfonate
Ppm	parts per million
py	pyridine
RNA	ribonucleic acid
RCM	ring-closing metathesis
ROM	ring-opening metathesis
rt	room temperature
Ru	ruthenium
S	Sulfur
Sat'd	saturated
Si	silicon
SM	starting material
TBSOTf	tertbutyldimethylsilyl triflate
TBAF	tetrabutyl ammonium fluoride
TMAF	tetramethyl ammonium fluoride
^{t}Bu	tertiary butyl
TFA	trifluoroacetic acid
THF	tetrahydrofuran
TLC	thin layer chromatography
TMSCl	trimethylsilyl chloride
TIPSCl	triisopropylsilyl chloride
TOS	target oriented synthesis
Ts	*p*-toluenesulfonyl
Val	valine

Chapter 1

Overview of Diversity-Oriented Synthesis Strategies

1.1. Introduction

The rapid evolution of diseases coupled with advances in biology poses new challenges in high throughput screening (HTS) efforts in drug discovery. Investigation of the function of disease genes have revealed the possibility of targeting cellular changes (One cell type from the other), protein-protein interactions and protein-DNA interactions for the treatment of human diseases.[1] Recent advances in biology have revealed the involvement of regulatory RNA as well as transcription factors in diseases.[1] In spite of these discoveries, the aforementioned target areas lie outside the paradigm of "druggable" chemical space[2] set forth within the pharmaceutical industry.[1] While target oriented synthesis (TOS) is aimed at achieving the synthesis of natural products that modulate a biological target of interest, medicinal chemistry / combinatorial chemistry approaches are aimed at the production of small molecules collections based around a small molecule of known biological activity. In contrast, diversity-oriented synthesis (DOS) aims to synthesize diverse collection of complex small molecules, in a systematic fashion to afford optimal screening collections that allows for interrogation of chemical space that has been deemed "undruggable" (Figure 1.1).[3]

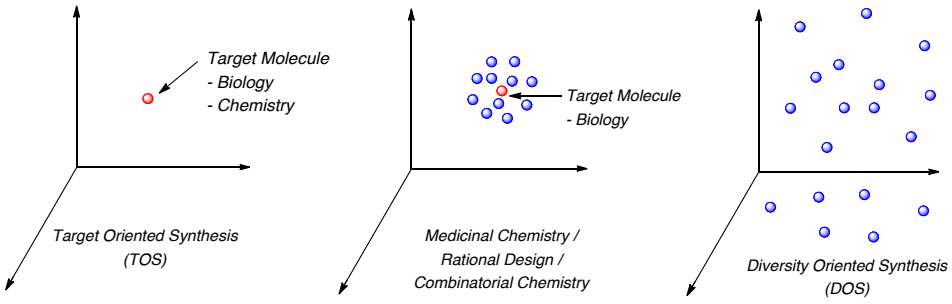


Figure 1.1

1.2. Fundamental Concepts in DOS

As mentioned above TOS involves the synthesis of a pre-selected target molecule that has known biological properties. The synthetic planning route is determined via retro-synthetic analysis[4]: breaking down of the complex target molecule into a series of smaller retrons, identifying the SM for the synthesis of the said retrons, followed by subsequent amalgamation of all the retrons to achieve the synthesis of the target molecule (Figure 1.2).[4] In contrast, DOS does not entail the synthesis of a particular target molecule but rather the synthesis of a collection of molecules that are optimal in terms of molecular diversity.[3] Planning strategies utilize the concept of forward chemical analysis from SM onward in a forward direction utilizing a product = substrate relationship taking advantage of the repertoire of available chemical methodologies to build-up molecular complexity thus emphasizing the method driven nature of DOS (Figure 1.2).[3g]

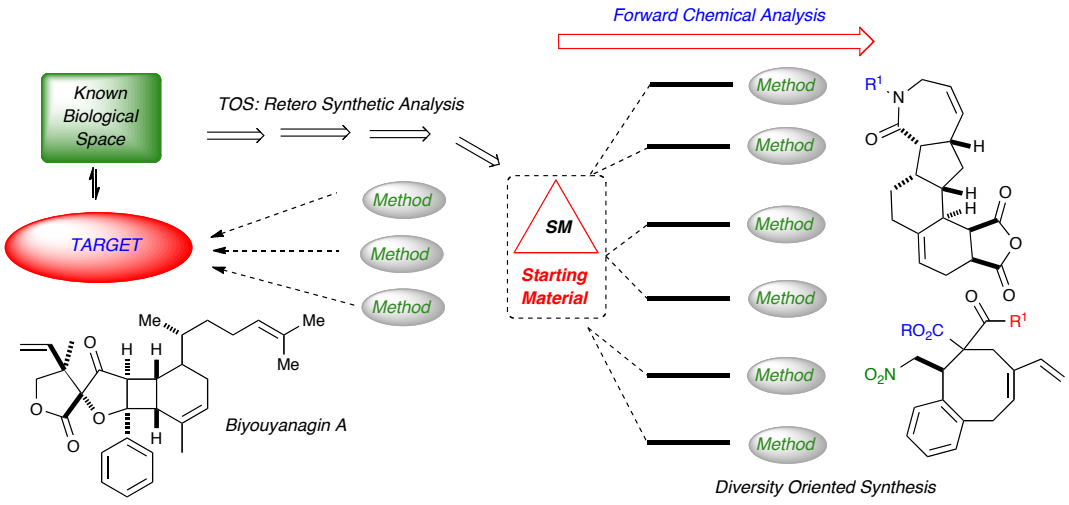


Figure 1.2

A collection of molecules has its diversity classified into 3 areas namely (i) appendage diversity, (ii) skeletal diversity and (iii) stereochemical diversity.

Appendage diversity is brought forth by different appendages which may either be static, unreactive functionalities (e.g. alkyl/ aryl side chains) or dynamic, reactive functionalities (e.g. amino groups, carboxylic acids, aldehydes, aryl/ vinyl halides etc) and can be exploited in library production via diversification reactions such as esterification, amidation, reductive aminations and metal-catalysed coupling reactions to name a few. The orthogonality (mutually exclusive reactivity) of these functional appendages are desired as this would then allow the use techniques of combinatorial chemistry for the synthesis of the entire possible matrix of products. These techniques include the use of split-and-pool, immobilized reagents and immobilized scavengers in the synthesis of libraries.[5]

Stereochemical diversity has powerful consequences and is achieved via design of a set of molecules containing multiple stereogenic centers and subsequent production of the entire matrix of possible stereoisomers. This allows for optimal coverage of the possible orientations that a molecule can have in its interaction with macromolecules such as proteins. Identification and development of stereospecific / stereoselective reaction processes have a high value in this regard.

Skeletal diversity is achieved by introducing cyclization pathways capable of producing different ring systems and or ring sizes. Consequently, a premium is placed upon the development and discovery of chemical methodologies that allow for the synthesis of diverse ring systems. Different ways of achieving skeletal diversity will be discussed in detail in the context of advances in DOS strategies.

Lastly, the achievement of molecular complexity is desired in planning DOS strategies. This is due to the dependence of many biological processes on protein-protein interactions, which are disrupted by complex, naturally occurring molecules themselves. Furthermore, increasing the number of protein binding elements as well as introduction of molecular rigidity is preferred for the binding of molecules to protein-protein interaction sites.[6]

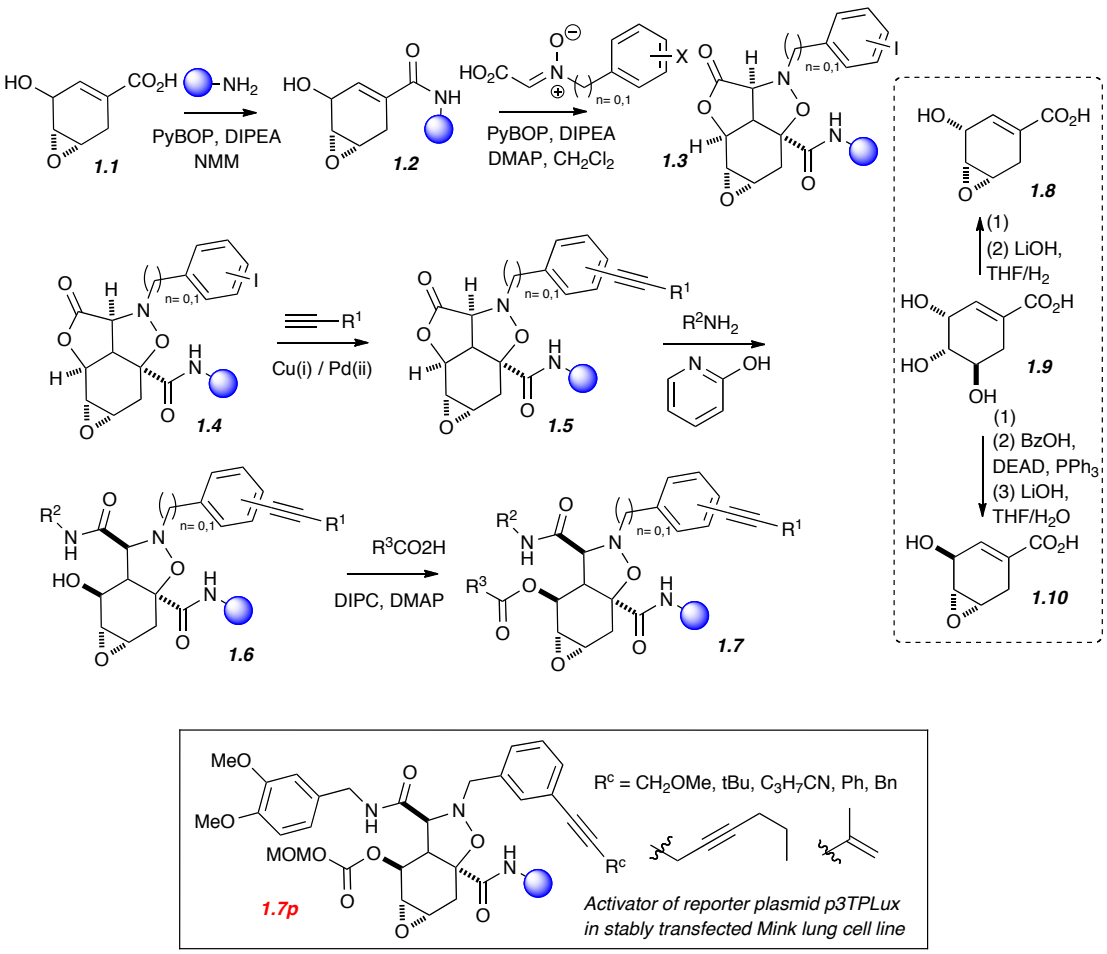
Since the publication of seminal work by the Schreiber group that set the stage for DOS approaches to drug discovery, this area has evolved rapidly in recent years.[6] This chapter aims to provide a brief overview of recent development as well strategies in DOS.

1.3. Advances in DOS Strategies

The initial work reported by Tan and coworkers involved the synthesis of a 2-million member library of natural product-like molecules for the discovery of non-natural protein-binding ligands.[7] This entailed the utilization of Shikimic acid as a template in combination with split and pool synthesis.[8] Both antipodes of the Shikimic acid epoxide were initially synthesized via procedures established previously by the Schreiber labs,[9] followed by immobilization on to a supported amino resin. Subsequent one pot tandem [3+2] cycloaddition – lactonization utilizing aryl nitrone carboxylic acids afforded an array of immobilized tricyclic scaffolds containing a lactone and an aryl iodide for functionalization. Thus, 18 tetracyclic scaffolds were produced followed by a 3-step diversification protocol to construct a large library of these non-natural ligands. Sonogoshira coupling with an array of alkynes were carried out at the aryl iodide initially.[10] This was followed by opening

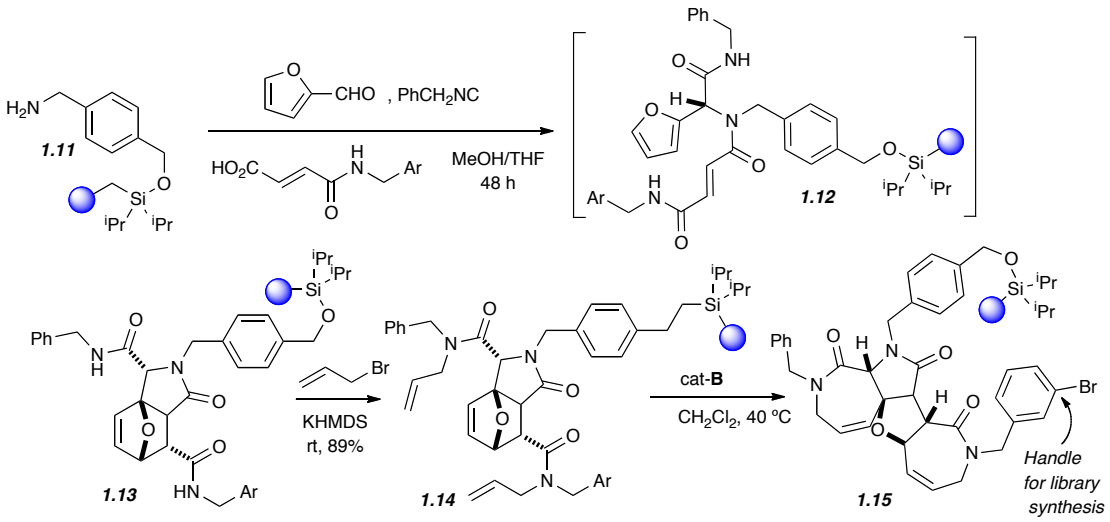
of the lactone utilizing a variety of amines and subsequent esterification with the resultant hydroxy group. Thus the authors have reported the utilization a combination of 30 alkynes, 62 amines and 62 carboxylic acids to produce a library of 2.18 million stereochemically defined, structurally diverse compounds. Subsequent biological assays provided several compounds (**1.7p**) that were found to activate the reporter plasmid p3TPLux in a stably transfected Mink lung cell lines (Scheme 1.1). This report represents the initial foray into the synthesis of libraries utilizing a DOS philosophy and introduces the concept of appendage diversity in regard to DOS.

Scheme 1.1



The report by Lee and Schreiber in 2000 is looked upon as the work that formally introduced the concept of DOS. It is considered to be the first publication on DOS strategies and has inspired much of the work that followed it.[6] This work outlines a key concept of forward synthetic planning in DOS, namely the pair-wise use of complexity generating reactions for achieving structural complexity. This report by Lee and Schreiber utilized the pairing an Ugi multi component reaction (MCR) in tandem with an intramolecular Diels-Alder reaction to generate a polycyclic system.[6,13] This was then followed by the use of a ring opening-ring closing metathesis reaction to generate a complex polycyclic molecular system containing several orthogonal appendages for the generation of libraries utilizing combinatorial methodologies (Scheme 1.2).

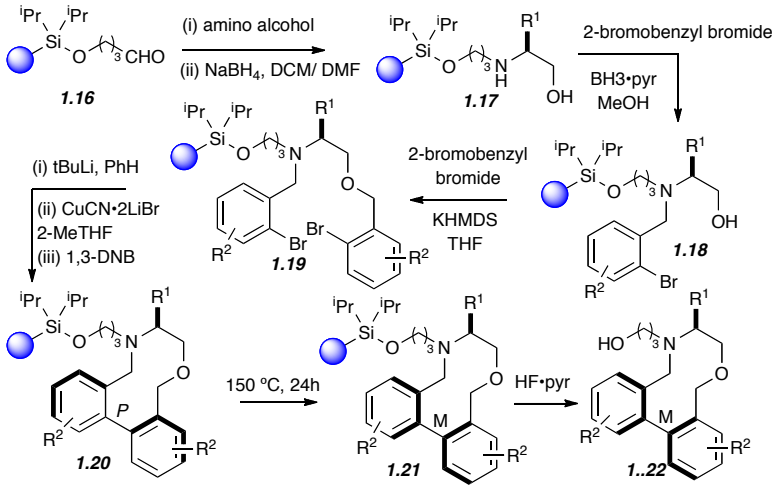
Scheme 1.2



In 2002, Spring and coworkers reported the use of biaryl coupling-based DOS approach to medium sized ring systems in conjunction with a one bead-one stock solution platform toward the discovery of several biological probes. The medium-

sized rings were constructed via a 3 step process whereby supported aldehydes were subjected to reductive amination with amino alcohols followed by a second reductive amination with a variety of 2-bromobenzaldehydes to furnish the corresponding 3º amine. Subsequent alkylation of the alcohol with a variety of 2-bromo benzyl bromides followed by intramolecular Cu-catalyzed biaryl coupling completed the synthesis of the medium sized rings. Efforts were made to obtain the possible atropdiastereoisomers by varying temperature as it was revealed during validation studies that the M atropdiastereomer of a set of molecules was active in a zebra fish assay over the P atropdiastereomer. Overall a library with a theoretical population of 1412 was prepared and subject to plant and zebrafish developmental assays utilizing this DOS approach (Scheme 1.3).[11]

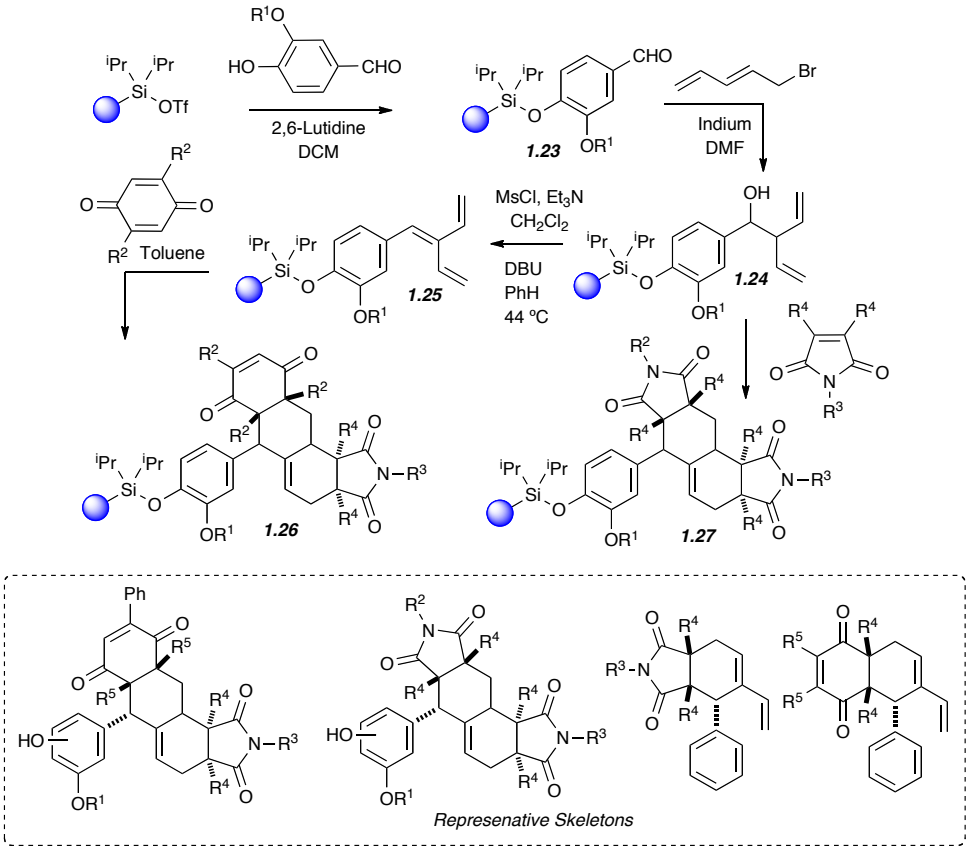
Scheme 1.3



In another significant development, Kwon, Schreiber and co-workers reported a DOS strategy utilizing a branching pathway to skeletal diversity.[12] This approach entailed the synthesis of an immobilized triene followed by consecutive Diels-Alder cycloaddition.[13] Efforts commenced with immobilization of an array of 4-hydroxy

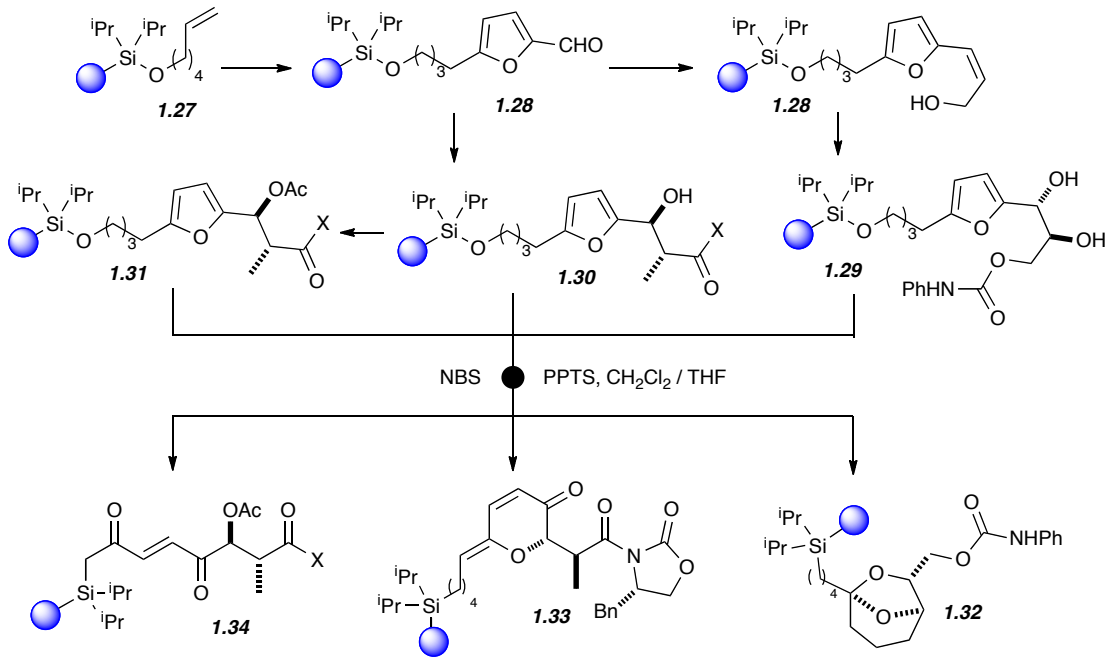
benzaldehydes via silylation of the phenol. Indium-mediated allylation followed by dehydration afforded the requisite trienes. The Diels-Alder branching pathway utilized the discovery that tetra- and tri-substituted dienophiles underwent mono cycloaddition while disubsituted dienophiles underwent bis cycloaddition. Thus one pathway involved the sequential use of the phenyl-substituted benzquinone and maleimide to furnish 6,6,6,5-tetracyclic systems (**1.26**) while use of maleimide resulted in the production of 6,5,6,5-teatracyclic systems (**1.27**). Investigations also revealed that use of halogenated dienophiles furnished three other distinct polycyclic systems. Overall, the investigators employed this branching pathway to produce 10 different skeletons and 29400 compounds (Scheme 1.4).

Scheme 1.4



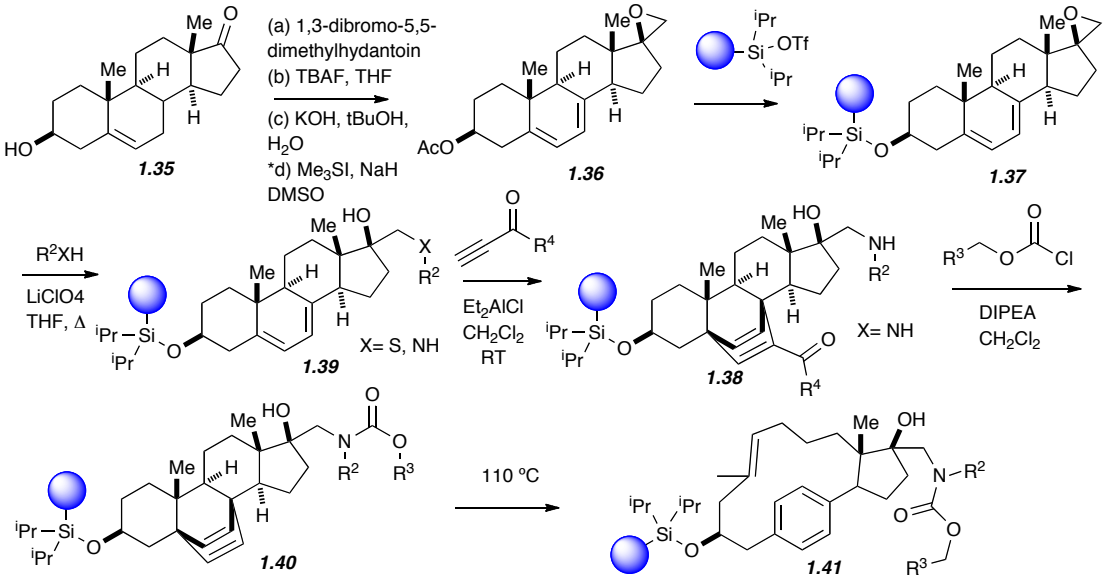
In another significant development Burke and coworkers described the combinatorial approach to achieving skeletal diversity. This approach involves subjecting substrates with common core scaffolds to a common set of conditions to generation multiple skeletons. Skeletal information is encoded into the scaffolds and are identified as σ-elements. These are nucleophilic functionalities such as hydroxyl and amino groups. Accordingly, immobilized furfuraldehyde **1.28** was produced and subjected to different conditions including sharpless-dihydroxilation and aldol addition conditions to furnish an array of immobilized hydroxy furans. Each of the supported hydroxy furans **1.29 – 1.30** were subject to NBS in 4:1 THF/H_2O and PPTS in CH_2Cl_2 to afford an array of diverse skeletons via a series of rearrangement reactions (Scheme 1.5).[14]

Scheme 1.5



Kumar and coworkers have described a skeletal transformation strategy to produce an array of diverse small molecules. This approach takes advantage of a reaction developed by Winterfeld and coworkers and involves a Diels-Alder – retro Diels-Alder reaction of steroidal dienes. Dehydroandrosterone-3-acetate was subjected to Corey-Chaykovsky epoxidation[15] to afford the desired core scaffold. The epoxide was subjected to ring opening with an array of amines followed by Diels-Alder reaction with a suit of ynones to furnish the corresponding diene. Modification of the 2° amine via acylation / sulfonylation epoxide ring opening followed by subsequent retro Diels-Alder reaction of the resultant adduct afforded the ring expanded product. A combination of 41 amines, 15 electrophiles and 12 ynones produced a library exceeding 4000 members of skeleletally diverse were products (Scheme 1.6).

Scheme 1.6



A powerful strategy for enabling DOS approaches to small molecule libraries known as the Build-Couple-Pair approach (B/C/P) was developed by Schreiber and co-workers. This development is considered to be a turning point in DOS strategies as it allows for obtaining matrices that are dense in stereochemical and skeletal diversity in a minimal number of steps.

The B/C/P approach consists of: (i) Build - Production of chiral building blocks via asymmetric syntheses such that the building blocks have functionalities that are orthogonal in terms of reactivity. A premium is placed upon obtaining the full matrix of stereoisomers (ii) Couple - Coupling of building blocks. Ideally desired conditions exclude stereochemical consequences. (iii) Pair - Pairing of functional groups via intramolecular reactions in "pair-wise" fashion. The orthogonality of the functional groups in the acyclic precursor is important in this regard (Figure 1.3).[16]

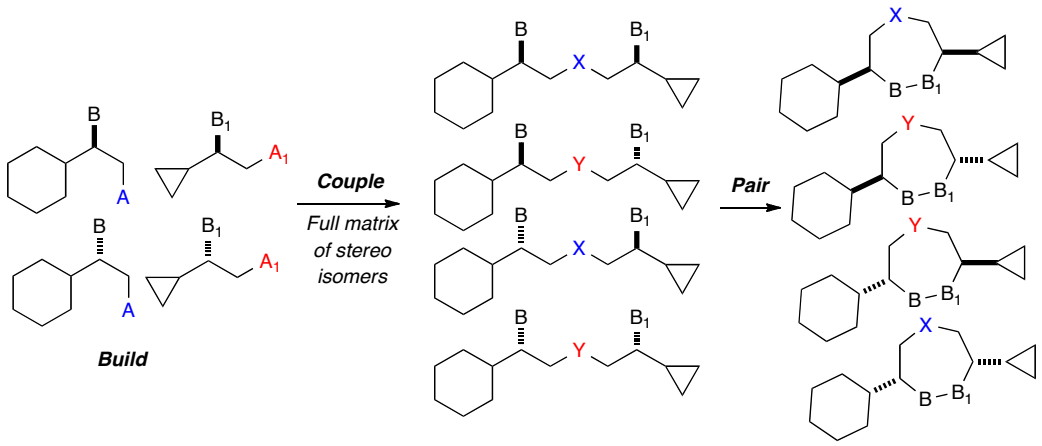
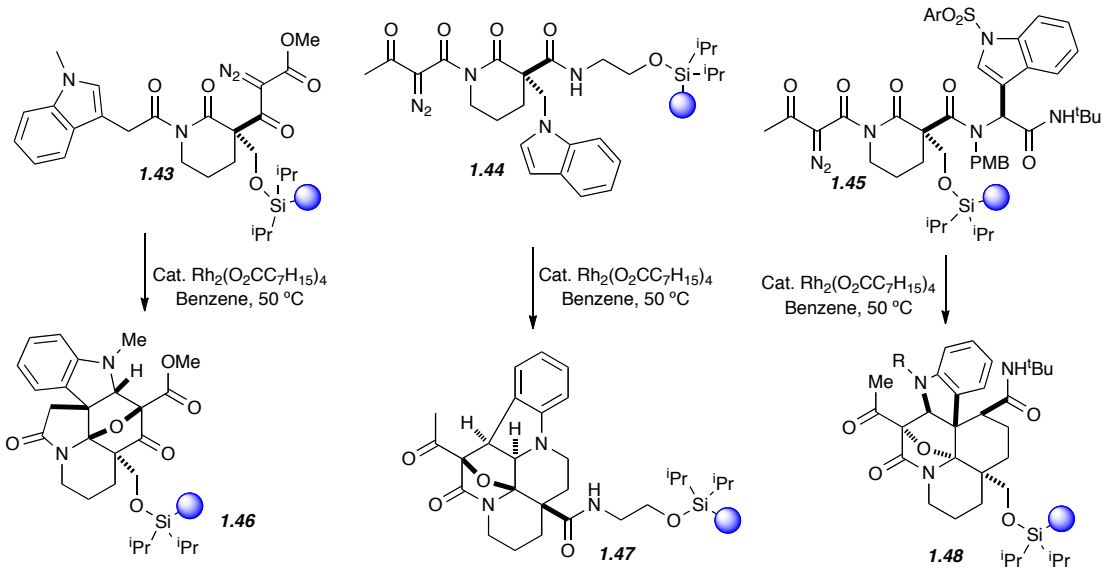


Figure 1.3

Oguri and Schreiber showcased this concept achieving skeletal diversity via multiple folding pathways.[17] This approach entails the introduction of a desired functional group at different positions of a core scaffold. Subjecting each of the

scaffolds to common reaction conditions affords diverse skeletons. Thus Rh(II)-catalyzed cyclization-cycloaddition reaction developed by Padwa[18] was selected as the reaction of choice. Placement of a-diazo-1,3-diketone and the its acyl reaction partner at differing position of the core indole lactam and subsequent subjection to the Padwa conditions resulted in the production of skeletally diverse complex polycyclic systems (Scheme 1.7).

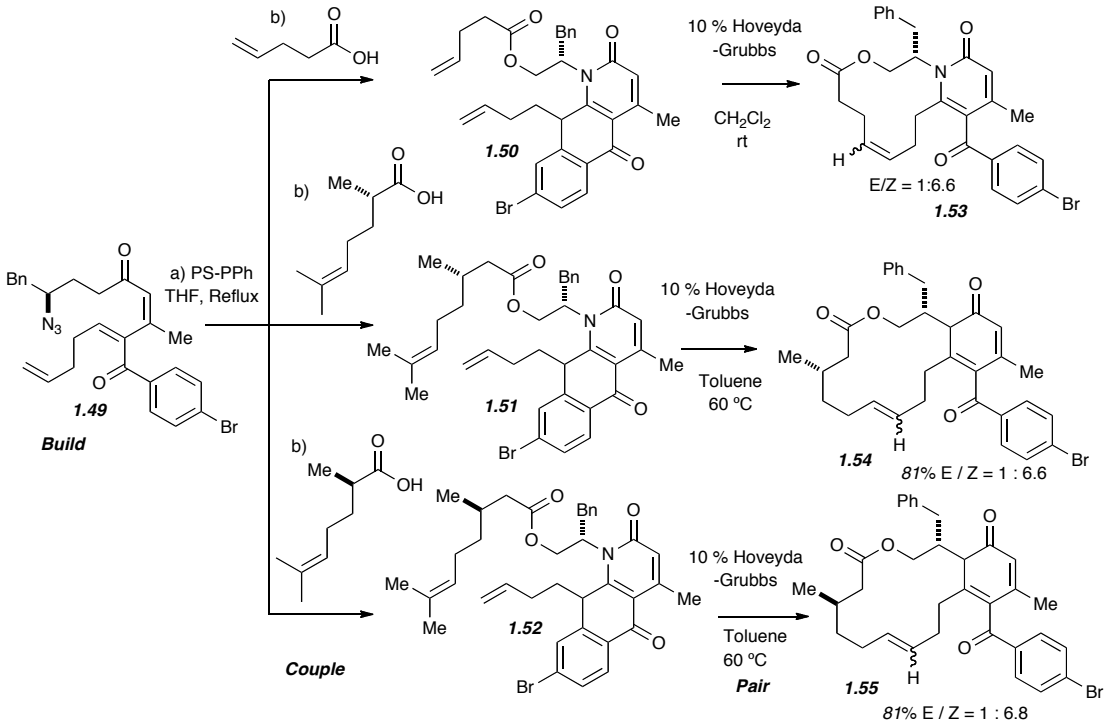
Scheme 1.7



Luo and co-workers have reported the development of a Staudinger – RCM based methodology and subsequent utilization in a B/C/P strategy inthe production of diverse macrocycles for HTS. [19,20,21] The build phase utilizes a Au(i)-catalyzed methodology for the synthesis of the azido dicarbonyl building block. The couple phase involved use of immobilized TPP via a Staudinger reaction to furnish an an oxazole intermediate followed by subsequent ring-opening by an alkenyl carboxylic acid to afford the requisite diene. RCM was subsequently utilized as the pairing

reaction to produce an array of diverse macrocycles.[20] Use of stereochemically diverse carboxylic acids enabled access to stereochemical diversity (Scheme 1.8).

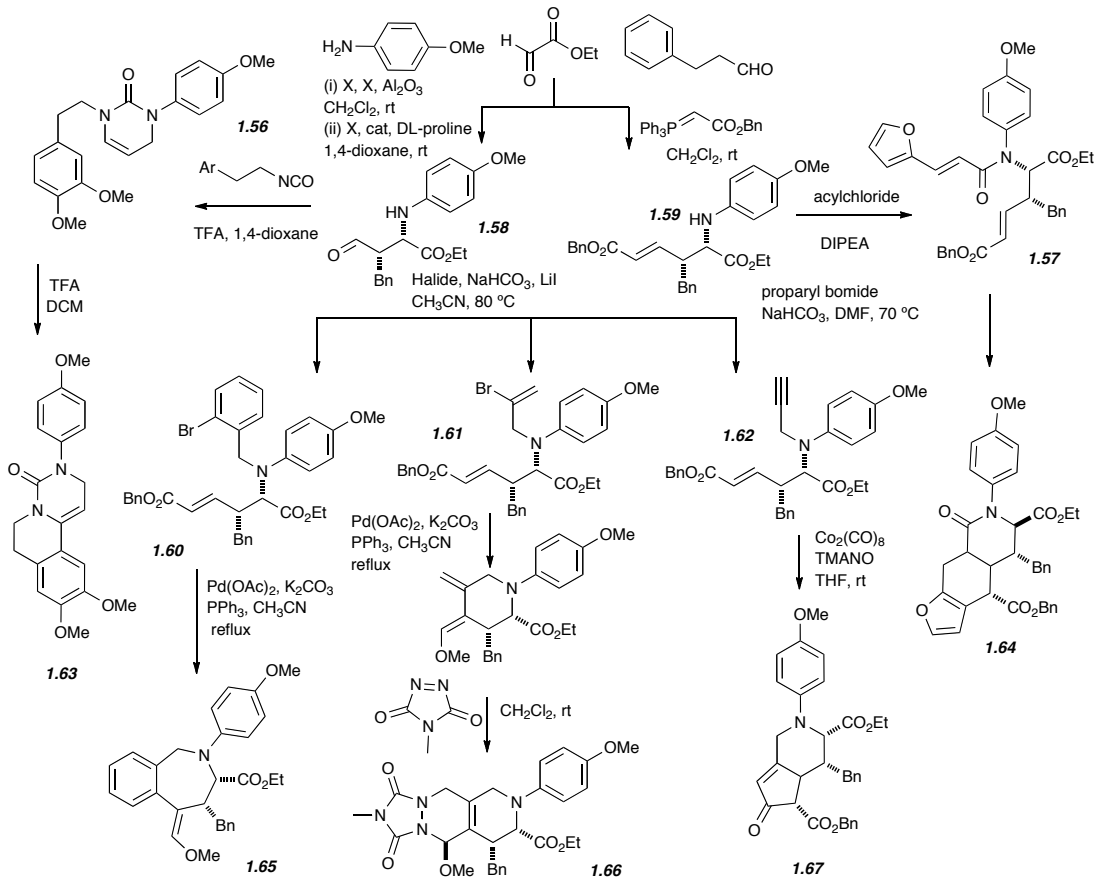
Scheme 1.8



In another report Uchida and coworkers have reported the utilization of the B/C/P approach in the production of a diverse array of N-containing heterocycles. A catalytic, enantioselective cross-Mannich reaction[22] involving achiral aldehydes, primary amines and ethyl glycolate is utilized in the build phase to produce the 2º amino formyl ester synthons. A Wittig reaction[23] with the aldehyde produced a 2º amino alkenyl ester as well. Both these building blocks were next subjected to benzylation / allylation / propargylation in the couple phase. Strategic use of different alkylations allowed for the utilization of different reaction pathways in the pairing phase. Subsequent pairing employed two pathways, an intramolecuar (IM) Heck

reaction and an intramolecular Pauson-Khand reaction for the production of diverse polycyclic N-containing heterocycles.[24,25] The IM Heck reaction with 2-bromo allyl bromide furnished a conjugated diene thus setting the stage for further manipulation via Diels-Alder reaction to increase molecular complexity (Scheme 1.9).[25] Variation of the coupling partners enabled expansion of scope in terms of skeletal diversity. Accordingly, acylation was carried out with different furanyl enoyl chorides in the coupling step and subsequent pairing via an electrocyclization reaction furnished diverse tricyclic N-containing skeletons. Additionally, utilization of isocyanates in the coupling step allows for urea formation, which is set up for a subsequent condensation reaction as a mode of ring closure.

Scheme 1.9



Subsequent 2° cyclizations were carried out via Friedel-Crafts akylation as well as a tandem amidation – addition sequence (Scheme1.9).[26]

In what is looked upon as a pivotal development, Porco and coworkers reported the concept of functional group pairing (FGP) for the synthesis of diverse skeletons.[27] This revolutionary approach entails the production of an acyclic precursor containing multiple (3 or more) reactive functional groups in such a way that allows for the pairing of 2 functional groups via intramolecular reaction pathways that do not affect the remaining functionalities. Thus multiple skeletons can be synthesized from a single acyclic synthon by employing different reaction pathways. (Figure 1.4)

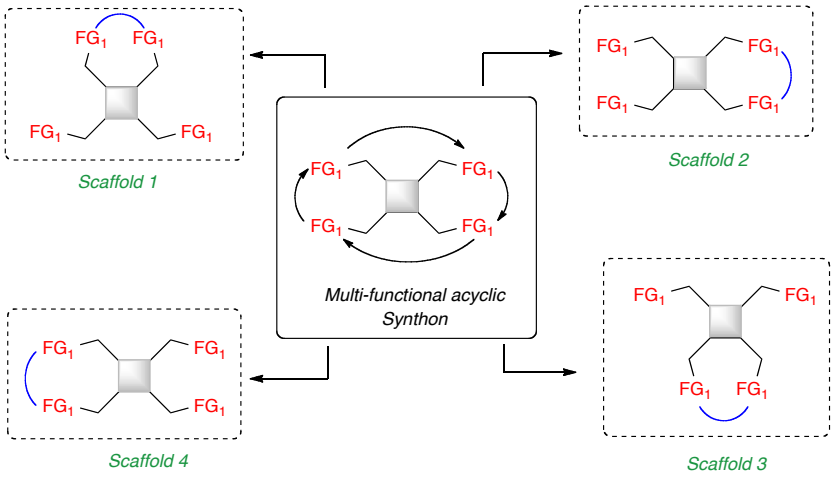
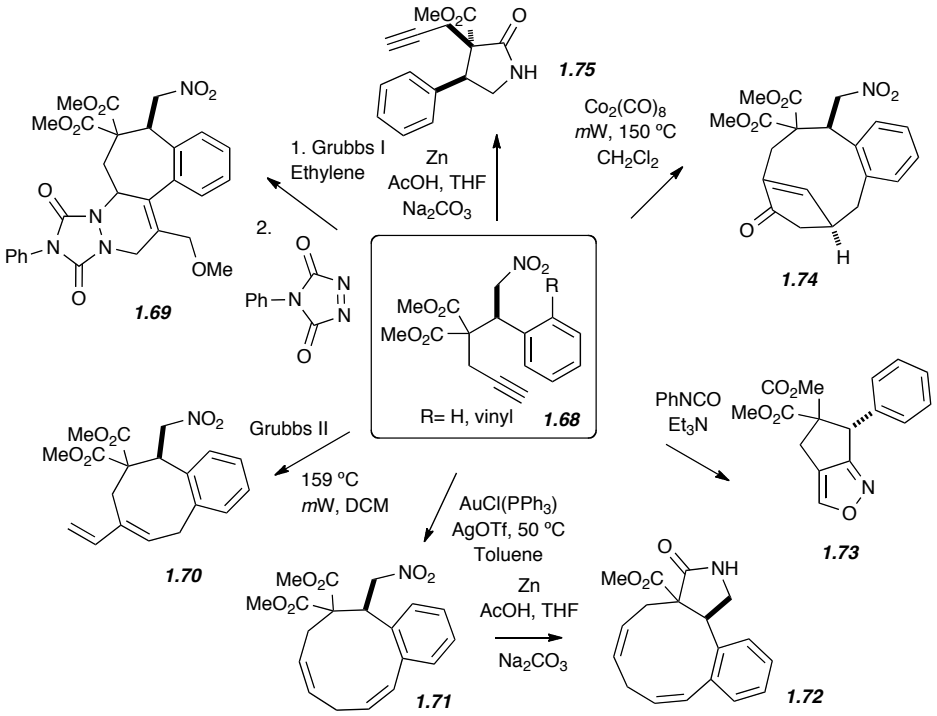


Figure 1.4

Thus, a multi-functional dicarbonyl precursor was established via an enantioselective Michael reaction.[28] Initial studies entailed the synthesis of a ene-yne nitro dimalonate synthon that allowed for the pairing of: (i) Alkyne-nitro via IM [3+2] cycloaddition, (ii) nitro reduction – amidation, (iii) alkene – nitro IM [3+2] cycloaddition, (iv) eneyne metathesis, (v) Pauson-Khand and (vi) Au-catalyzed

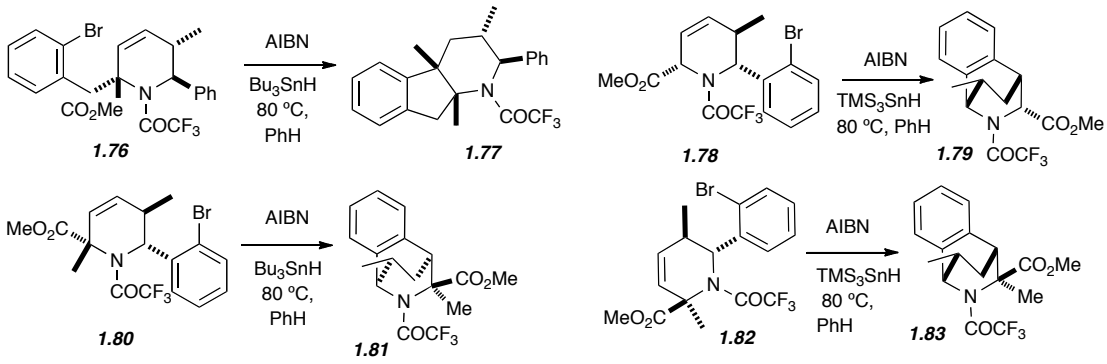
cycloisomerization.[12,24] Enyne metathesis was useful as it results in a diene and consequently allows for the utilization of Diels-Alder reactions for the synthesis (Scheme 1.10).[20]

Scheme 1.10



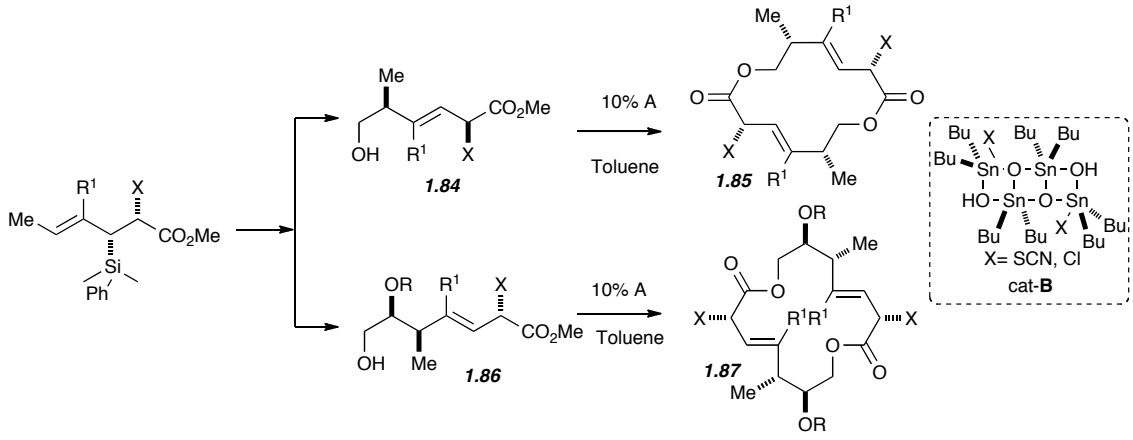
Panek and Porco have reported the use tetrahydropyridines as conformationally biased scaffolds employing radical pathways for the production of diverse skeletons.[29] Skeletal diversity was achieved by changing position of the point of radical intiation. This report represents the first use of radical cyclizaton techniques in DOS. (Scheme 1.11)

Scheme 1.11



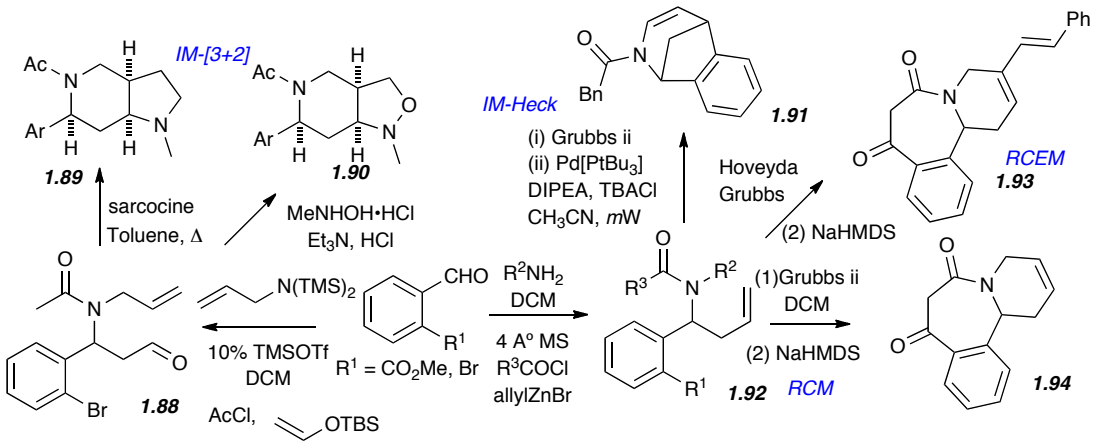
Porco and Panek have described a very effective but simple technique for accessing stereochemical diversity employing cyclodimerization in the synthesis of macrodiolides.[30] It was envisioned that subjecting hydroxy esters to transesterification conditions utilizing distannoxane transesterification catalysts would allow dimerization to afford macrodiolides. Thus C-6 as well as C-8 hydroxy esters were refluxed in Toluene in the presence of distannoxane catalyst (10%), cat-**B** to afford the desired 14-member and 16-member dimer product in good yields. Utilization of enantioenriched hydroxy esters synthesized via allyl silane chemistry[31] provided access to stereochemical diversity. (Scheme 1.12)

Scheme 1.12



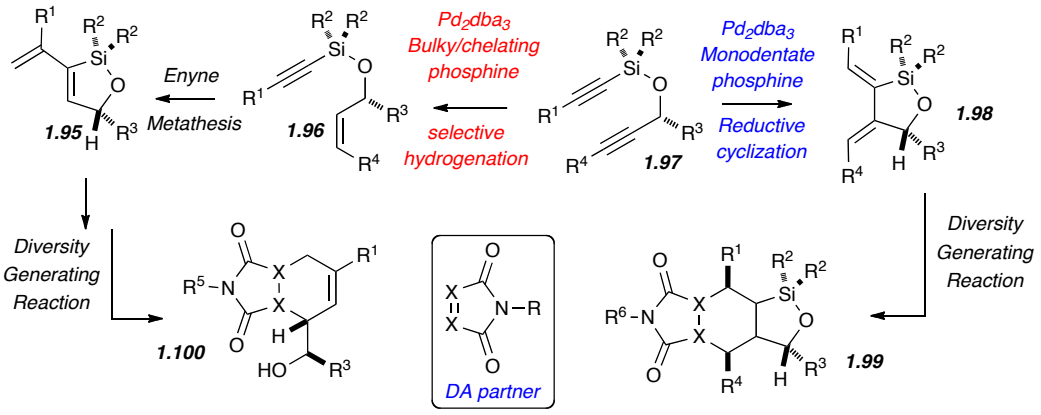
Martin and coworkers have reported an innovative approach to skeletal diversity via the employment of a 4-component multi component reaction (MCR) and subsequent cyclization protocols to produce diverse hetereocyclic systems.[32] Thus combination of aldehydes, amines and acyl chlorides generated N-acyl iminium ions that were subsequently trapped by an exogenous nucleophile to generate a multifunctional acyclic precursor. While the utilization of allyl / propargyl amine and formyl benzoates with barbier allylation[33] allowed for a Dieckman Cyclization[34] – RCM / RCEM approach to triyclic β-keto amides, use of α-bromo benzaldehydes with above conditions enabled utilization of IM-Heck[26] reaction to furnish bridged skeletons. Another route was also developed whereby amination of benzaldehydes with bis-(trimethylsilyl)allyl amine, acylation and treatment with silyl ketene acetal in the precence of TMSOTf furnished amide **1.92**. Pairing the amide **1.91** with an IM [3+2] dipolar cycloaddition with azomethine ylides generated N-containing polycyclic systems **1.89** and **1.90** respectively (Scheme 1.13).

Scheme 1.13



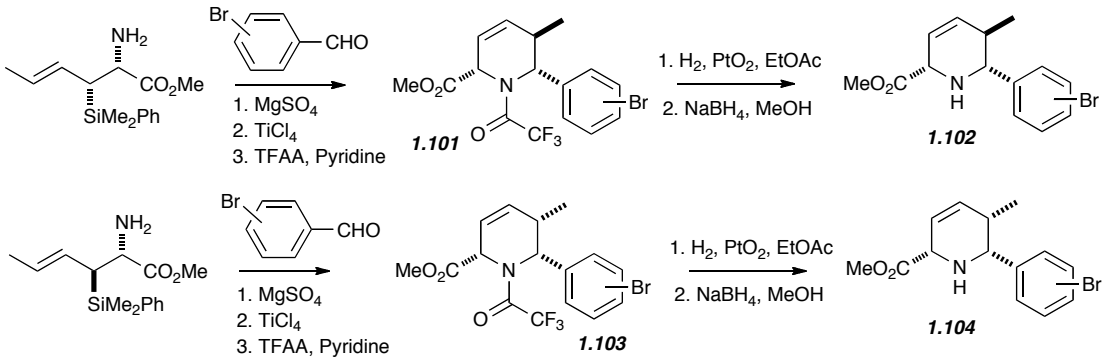
Schreiber and coworkers have reported the utilization of Pd-catalyzed reductive transformation of silyl ether tethered diynes to access skeletal diversity. This approach is aimed at mimicking nature's enzyme-mediated synthesis of skeletally diverse small molecules via minor perturbations of enzyme structure. The investigators have described an analogous process whereby slight modification of ligands of transition metal catalyst-mediated mediated transformations of diyne affords a number of diverse unsaturated precursor compounds, and coupled with complexity generating reactions such as Diels-Alder reactions, allows for the synthesis of skeletally diverse small molecules for high throughput screening (Scheme 1.14).[13,35]

Scheme 1.14



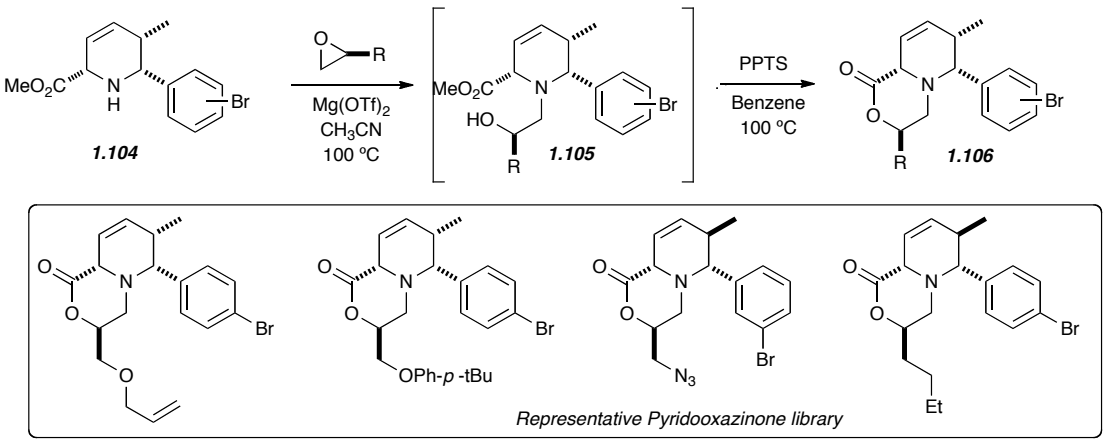
Panek and coworkers have recently reported the synthesis of stereochemically and skeletally diverse pyridooxazinones and pyridodiazapinones utilizing chiral pipecolate building blocks. The pipecolate building blocks were synthesized via [4+2] annulation of amino-silanes with bromobenzaldehyde. Thus, utilization of both *syn* and *anti* silanes along with both *m*- as well as *o*-bromoebnzaldeyde afforded four stereochemically diverse chiral building blocks (Scheme 1.15)

Scheme 1.15



A number of chiral epoxides were subjected to $Mg(OTf)_2$ catalyzed ring opening with the pipecolate esters followed by acid catalyzed trans esterification to produce a 14-membered library of diverse pyrdooxazinones (Scheme 1.16).

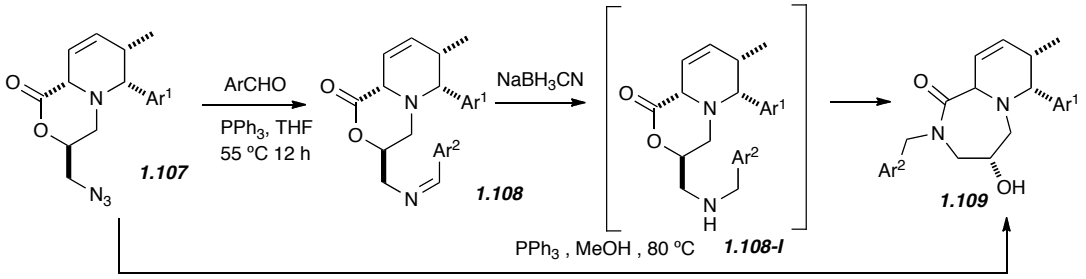
Scheme 1.16



The azidooxazinones were then subjected to an intramolecular aza-Wittig reaction to afford the ring expanded hydroxy pyridodiazepinone. This method was then expanded upon whereby, the azido oxazinone employing an intermolecular aza-Wittig reaction[19] with a series of benzaldehydes followed by reductive amination produced the amino oxazinone inermediate **1.108-I** which upon further reaction afforded the diazepine **1.109**. Stereochemical diversity was achieved via the

production of topologically diverse pipecolate scaffolds utilizing amino silane building blocks (Scheme 1.17).

Scheme 1.17

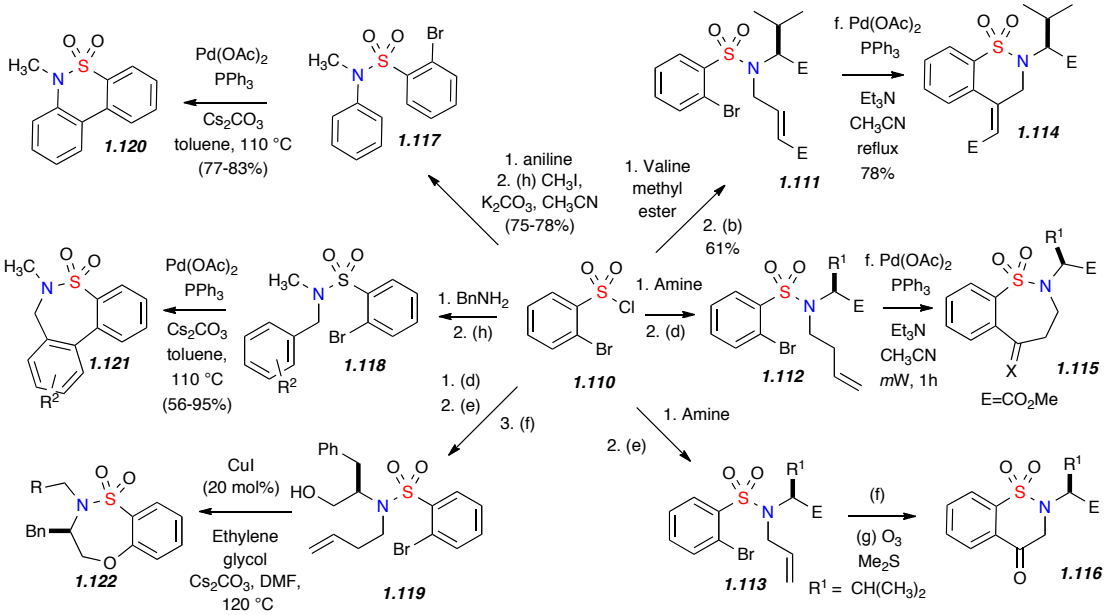


Hanson and coworkers have reported a sulfonamide linchpin approach employing a variety of new reaction pathways toward the synthesis of skeletally diverse benzofused sultams. These methods employ commercially available α-haloaryl sulfonyl chlorides in a amine reaction to establish the pivotal sulfonamide linchpin. A number of reaction pathways including Heck, lithiation, Sonogashira[10]-NH addition, Sonogashira-Pauson-Khand,[24] *C*- and *O*-arylations were were subsequently developed to produce 5, 6 and 7-membered sultams in good to excellent yields. [36]

Initial investigation explored Pd(0)-catalyzed Heck reactions[24] with olefin containing sulfonamides. Exposing these precursors to $Pd(OAc)_2$, Et_3N, CH_3CN (0.25 M) at 100 °C in a microwave and produced the corresponding products via 6-*exo*-trig (**1.114**) and 7-*endo*-trig (**1.115**) pathways. The chemistry of benzenesulfonamide was extended to an intramolecular arylation reaction whereby the α-bromo aryl sulfonamide group was paired with an aromatic group. Treating **1.110** with aniline and subsequent alkylation with methyl iodide or ethyl iodide

produced the corresponding sulfonamide **1.117**, which was subjected to $Pd(OAc)_2$, PPh_3, Cs_2CO_3 in toluene at 110 ºC affording cyclized product **1.120** via a *C*-arylation pathway. Treatment of **1.110** with benzyl amine and subsequent alkylation with methyl iodide furnished **1.118**, which was again subjected to $Pd(OAc)_2$ conditions at 110 °C for 24 h to afford the 7-membered benzofused sultam **1.121** in 85% yield (Scheme 1.18).

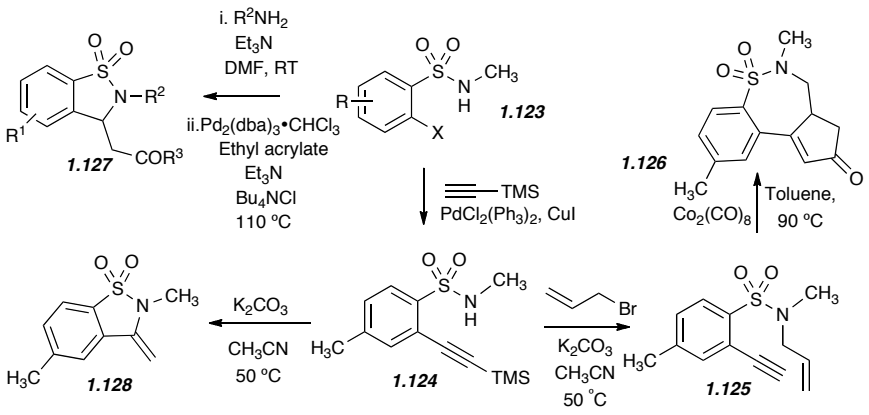
Scheme 1.18



The chemistry of α-halobenzenesulfonamide was further extended to both Pauson-Khand (PK)[24] and intramolecular hydroamination (IHA) reactions.[37] In this method, the α-bromoaryl sulfonamide group was attached to an alkyne under Sonogashira conditions and subsequently paired with both an alkene (PK) as well as an N-H (IHA). Compound **1.123** was subjected to Sonogashira reaction with trimethylsilyl acetylene in presence of $PdCl_2(PPh_3)_2$ and CuI to furnish sulfonamide

1.124. Alkylation of **20** with allyl bromide in presence of K_2CO_3 in CH_3CN at 50 ºC afforded allylated enyne product **1.125** along with a small amount of the corresponding IHA product **1.128**. However, when the reaction of **1.124** was carried out in the same conditions in the absence of allyl bromide, sultam **1.124** was produced as the sole product in 78% yield, representing a formal intramolecular hydroamination of an acetylene via a 5-*exo*-cyclization pathway. Finally, treatment of sulfonamide enyne **1.125** with $[Co_2(CO)_8]$ under thermal conditions (90 ºC) furnished the tricyclic Pauson-Khand product **23** in 67% yield. The application of α-haloaryl sulfonamides toward a domino aza-Michael-Heck protocol was also utilized, where by initial Michael addition of the sulfonamide into methyl propiolate, followed by an intramolecular Heck reaction yields the corresponding benzofused sultam **1.127** (Scheme 1.19).

Scheme 1.19



A DOS strategy termed "Click, Click, Cyclize" has been reported by Hanson and coworkers.[38] This approach relies on functional group (FG) pairing between a vinyl sulfonamide and an array of functional groups to synthesize skeletally diverse sultams. Several FG pairing pathways on central tertiary vinyl sulfonamide linchpins

have been developed including intramolecular Heck,[24] aza-Michael, ring-closing enyne metathesis, Pauson-Khand[24] and chemoselective oxidation/Baylis-Hillman reactions.[39]

The first pathway investigated commenced with two "click" reactions yielding tertiary vinylsulfonamide **1.129**, which underwent a regioselective 6-endo trig intramolecular Heck cyclization to afford the d-sultam **1.130** (Scheme 1.20, pathway A). The use of a TBS-protected amino alcohol and propargyl bromide for the first and second "click" reactions, respectively, produced the tertiary sulfonamide linchpin **1.131** (Scheme 1.20, pathway B). Intramolecular enyne metathesis yielding sultam **1.133**, whereas TBAF deprotection initiates an intramolecular oxa-Michael cyclization to afford **1.132**.

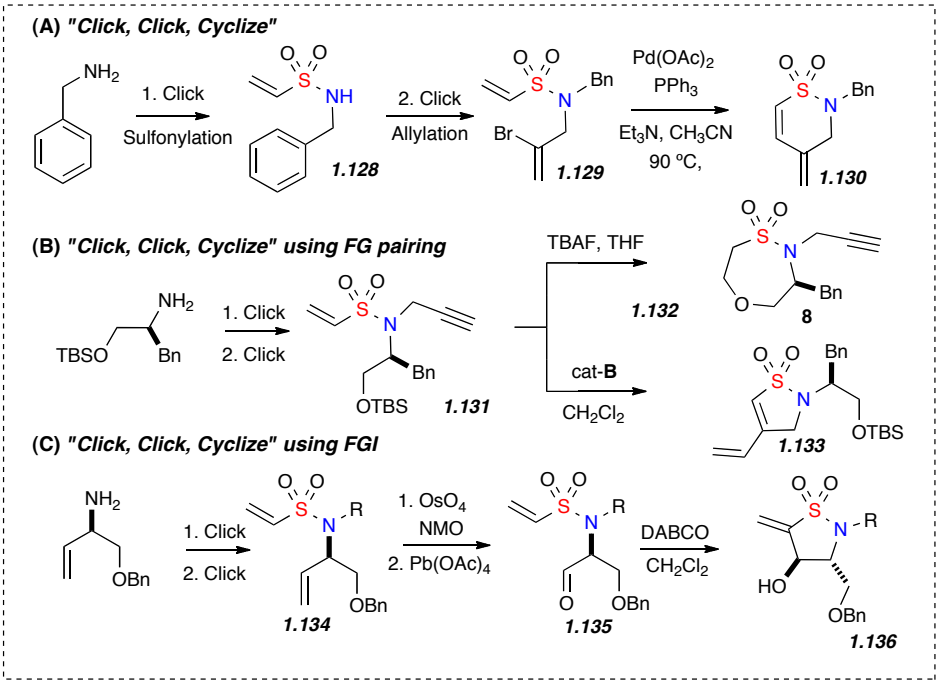
Use of FG interconversion (FGI) was utilized to broaden the reaction manifold by allowing for a new FG pairing event (Scheme 1.20, pathway C). Oxidation with OsO_4/NMO/$Pb(OAc)_4$ followed by DABCO-initiated Baylis-Hillman cyclization[39] affords the g-sultam **1.136** in 86% yield (dr = 4:1).

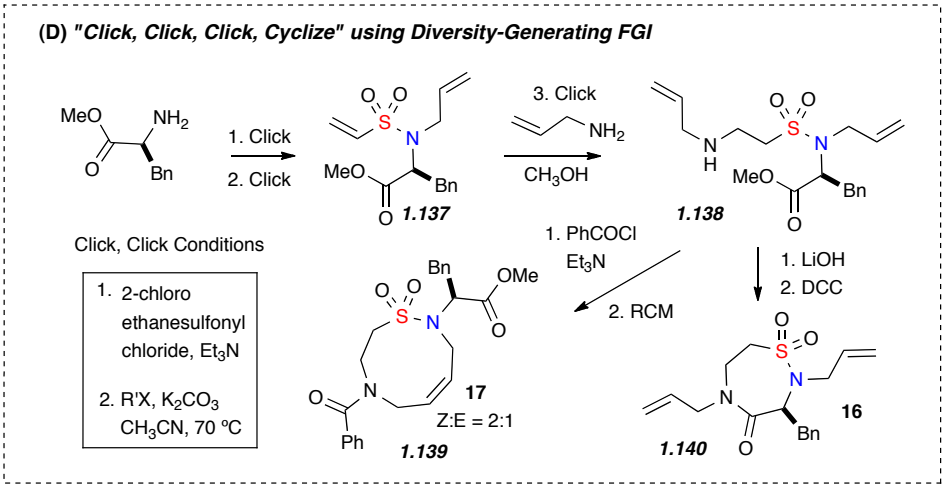
A fourth pathway utilizes an aza-Michael reaction in a "Click, Click, Click, Cyclize" reaction sequence, which effects an umpulong functional group interconversion (FGI) of an electropilic vinyl sulfonamide into a nucleophilic amino sulfonamide (Scheme 1.20, pathway D). This latter concept represents a diversity-generating step and offers a new pattern of FG pairing between the nucleophilic amine (NHR^2) and remaining FGs.

In this study, it was found that **1.137** underwent facile aza-Michael reaction to afford sulfonamide **1.138** in excellent yield. Subsequent basic hydrolysis and

intramolecular lactamization, yields the 7-membered sultam **1.140**. Alternatively, reaction with benzoyl chloride, followed by RCM, produces the 9-membered sultam **1.139** (Scheme 1.20).

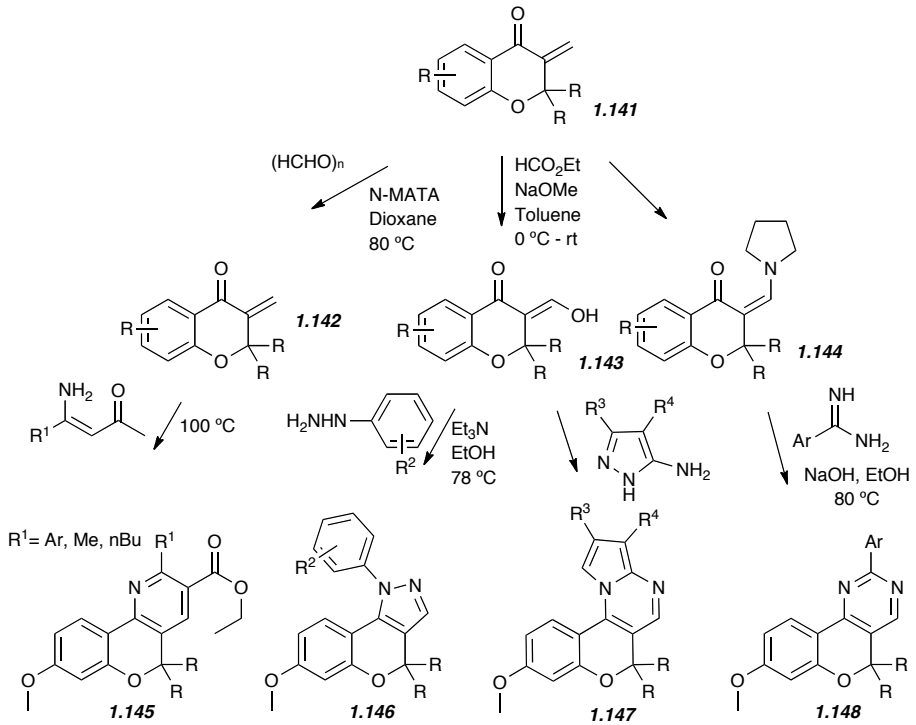
Scheme 1.20





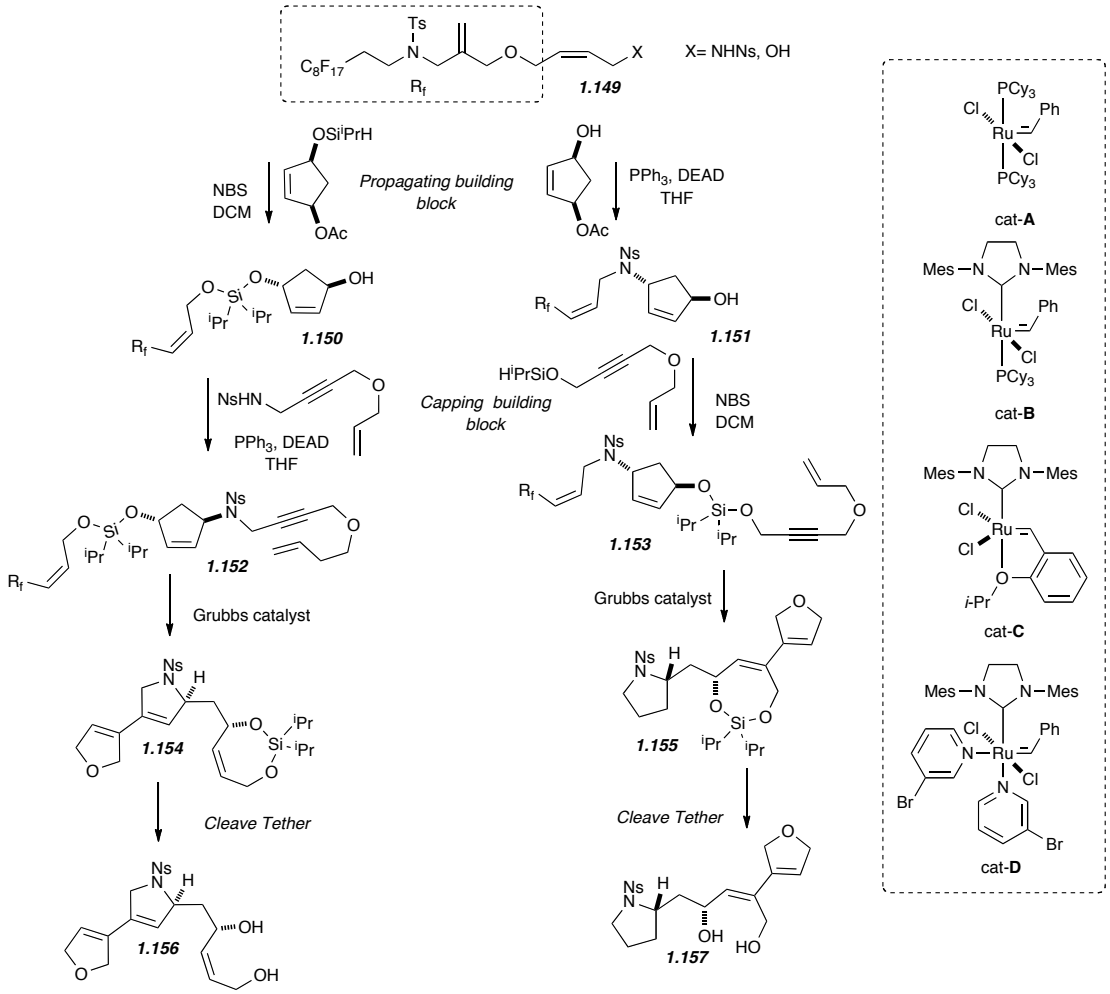
The concept that privileged scaffolds were preferred for interaction with biological receptors was devised by Evans and coworkers[40], and since then has been a cornerstone of medicinal chemistry approaches to probe development.[41] A rational approach to DOS strategies toward the synthesis of probe collections was reported by Park and coworkers and involves the utilization of privileged motifs as templates for the production of diverse molecules. Park's work utilizes benzopyrans due to a well precedented biological profile for these structural motifs.[42] Thus enone benzopyrans were prepared via a 2-step protocol and subjected to addition of a variety of nucleophiles including enamines, aryl hydrazines, amino pyrazoles and guanidines to produce the corresponding benzopyranpyridines, benzopyranylpyrazoles, benzopyranpyrimidines, and benzopranylpyrazolopyrimidines. (Scheme 1.21)

Scheme 1.21



More recently, Nelson and coworkers have reported a novel metathesis-based DOS approach for the production of diverse skeletons.[43] This approach involves appending olefinic building blocks to a fluorous tagged linker. The building blocks are classified as (i) propagating building blocks - based on ability to partake in ring opening metathesis (ROM) reactions and (ii) capping building blocks – allows for intercept ROM cascade. The metathesis cascade generates a structural motif containing heterocycles as well as silaketal tethers. Subsequent deprotection affords diol containing scaffolds.

Scheme 1.22



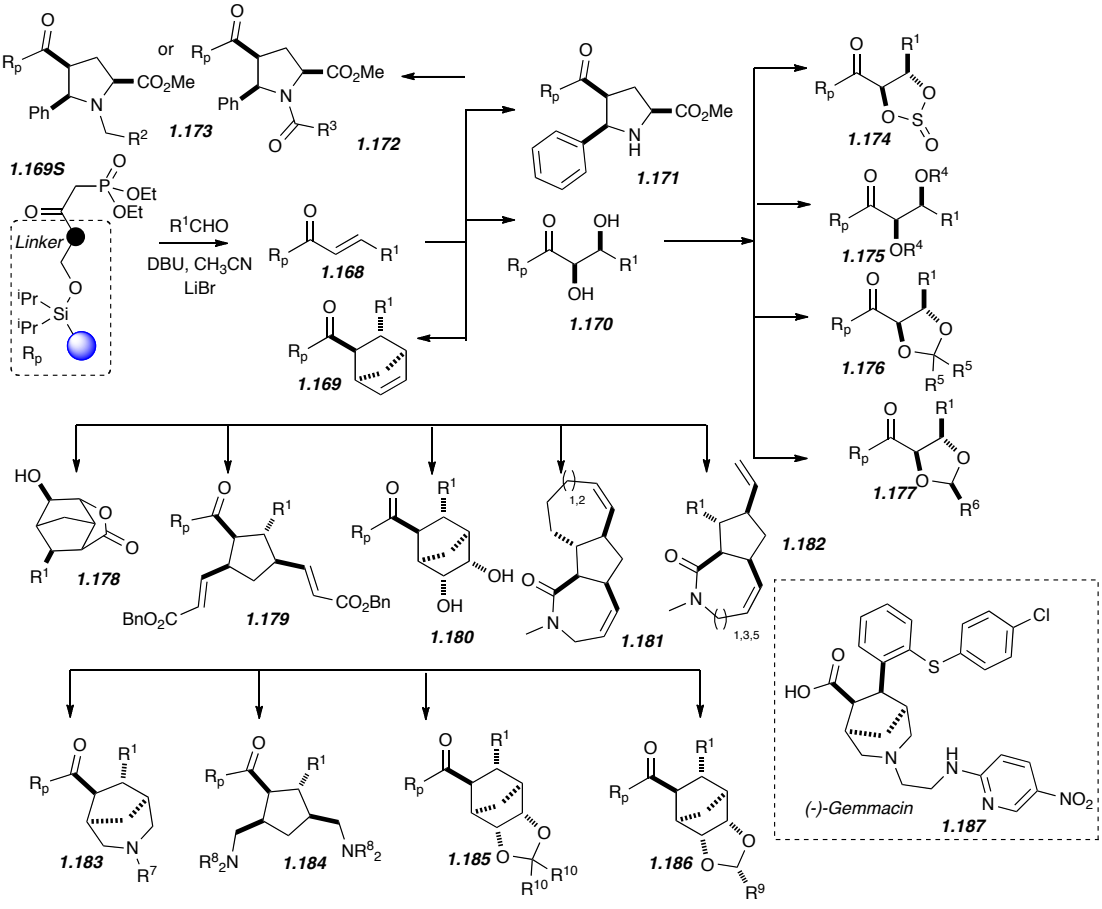
Notably, by utilizing the two building blocks in a combinatorial manner the authors have reported the synthesis of a 80 member library of diol containing skeletons. Also noteworthy is the use of the fluorous tag as this allows for the utilization fluorous solid phase extraction (SPE) cartridges for removal of excess reagents at each step (Scheme 1.22).

1.4. Recent Discoveries of Biologically Active Probes via DOS Platforms

Spring and coworkers have recently reported the discovery of an anti MRSA (Methicillin resistant *Stephylococcus aureos*) in the synthesis of a probe compound library utilizing a DOS approach.[44] This DOS approach by Spring and coworkers utilizes an immobilized phosphonate as the platform on which molecular complexity is built up in a convergent manner. Treatment of phosphonate **1.169S** with an array of aldehydes allows for formation of acyl α,β-unsaturated imidazolidinones. The utilization of three enantioselctive pathways including: (i) [3+2] cycloaddition, (ii) dihydroxylation and (iii) [4+2] cycloaddition generated an array of compounds belonging to three distinct skeleton classes. Each of the scaffolds was subjected to complexity generating reactions including acylation, acetal formation and a sulfonylation – azidation - [3+2] cycloaddition sequence to name a few. Each reaction step provided a probe compound. Particular advantage was taken of the norbornene containing scaffold via myriad reaction pathways to afford a variety of skeletons. Of noteworthy mention is the use of a ring closing – ring opening metathesis cascade to afford 7,5,7-tricyclic skeletons. Overall this approach afforded 242 small molecules belonging to 18 distinct skeletal classes. The library of compounds generated were screened against 03 strains of *S. aureus* and three compounds were found to inhibit

growth of these three strains. Among these compounds exhibiting anti-bacterial activity, (-)-gemmacin was found to exhibit broad-spectrum Gram-positive antibacterial activity in vitro, including growth inhibition of vancomycin-intermediate *S. aureus* as well as vancomycin-resistant enterococci. Subsequent SAR studies yielded a more potent analog of (-)-gemmacin.[45](Scheme 1.23)

Scheme 1.23



Schreiber and coworkers have reported the discovery of a small molecule, robotnikinin that binds the extracellular sonic hedgehog protein (Shh) and blocks Shh signaling in cell lines, human primary keratinocytes as well as a synthetic model of human skin.[46] Small molecule microarrays containing approximately 10000

compounds were prepared via DOS methodologies were subject to a screen of bacterially expressed ShhN (N-terminal fragment of full length Shh) and yielded a number of macrocyclic compounds that tested positive to this assay. SAR studies thereafter revealed a 12-member macrocycle identified as robotkinin that displayed ShhN binding capacity between 1.56 μM and 25 μM with a K_d of 3.1 μM and also exhibited concentration dependent inhibition of ShhN pathway activation. Significantly, the discovery of robotkinin represents the first known discovery of a small molecule that binds to Shh (Figure 1.5).

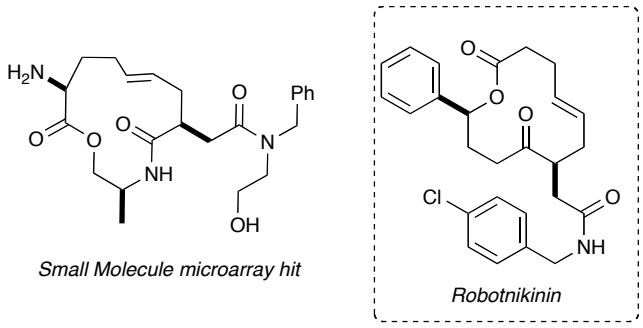
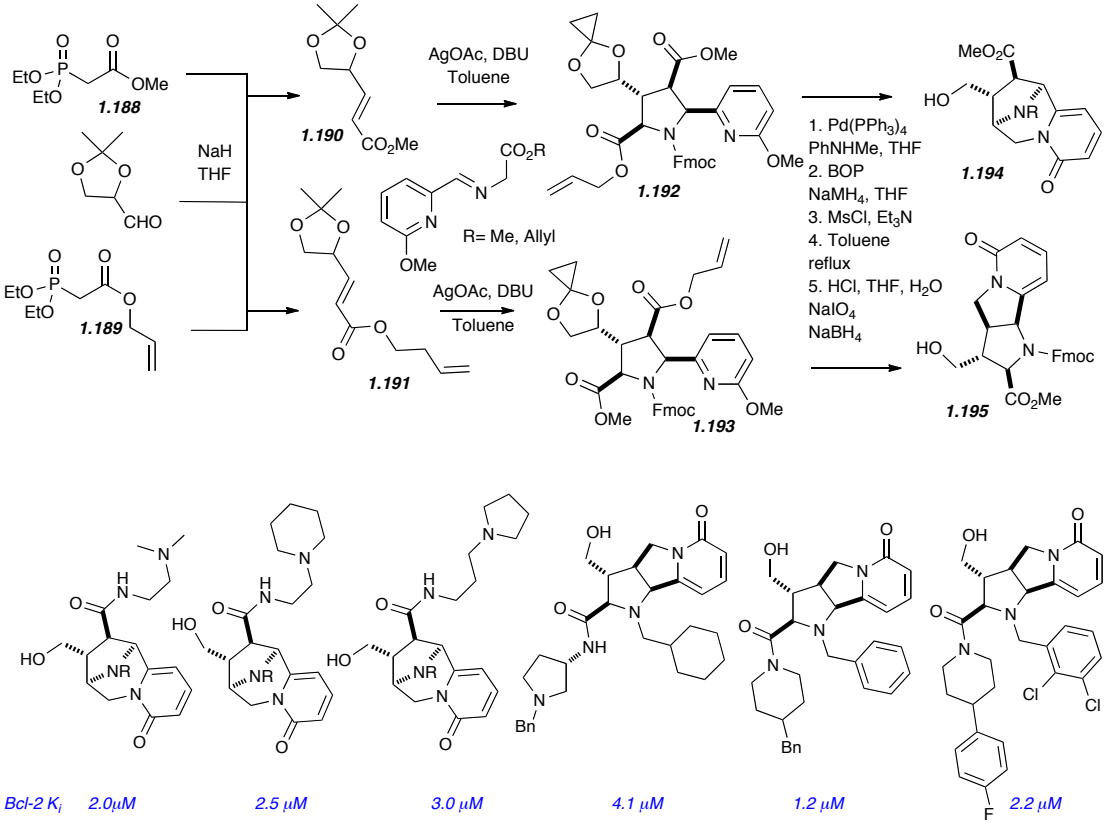


Figure 1.5

Marcaurelle and co-workers have recently reported the discovery of novel inhibitors of anti-apoptotic protein, Bcl-2[47] and was inspired by the natural product (-) – cytosine.[48] A DOS strategy commencing from phosphonate **1.188** and **1.189** and utilization of a series of complexity generating reactions furnished two classes of N-containing heterocyclic compounds, **1.194** and **1.195**. The complexity generating reactions employed included [3+2] dipolar cycloadditons of azomethine ylides to generate the pyrrolidine ring system. Solid phase techniques were subsequently utilized for the preparation of a library with a population of approximately 15000 compounds. The library was screened for binding affinity to Bcl-2 and Bcl-X and

provided a hit rate of 1.1% against Bcl-2 and 0.2 % against Bcl-X. In particular several compounds were found to exhibit K_i in the range 1.2 μM – 6.8 μM. This report is significant in that it demonstrates that, a primary screen of compounds was able to afford micromolar inhibitors of protein-protein interactions in spite of the difficulty of designing inhibitors of protein-protein interactions (Scheme 1.24).

Scheme 1.24



1.5. Conclusion

Diversity-oriented synthesis (DOS) has emerged as an enabling platform for the production of small molecules allowing access to broader regions of chemical space. DOS has evolved rapidly since its inception in 1998 and this chapter has attempted to provide an overview of the different strategies and philosophies devised for the implementation of DOS strategies. Among several features defining DOS, forward synthetic analysis and functional group pairing have surfaced as significant tools. The Build-Couple-Pair (BCP) concept reported by Schreiber and coworkers represents a powerful planning strategy within forward synthetic analysis for producing multiple scaffolds in the fewest possible steps while generating skeletal and stereochemical diversity.

The common feature in all of the different strategies developed for enabling efficient DOS production of small molecule libraries, is the methodology driven nature of DOS. Therefore, the development of strategies and chemical methodologies that affords facile access to scaffolds is of paramount importance. Equally important are metrics that provide a quantifiable property to the diverseness of a particular collection of molecules. In this regard the development of cheminformatics is a crucial tool for the successful implementation of DOS planning strategies.

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Chapter 2

Supported/Tagged Scavengers for Facilitating High-throughput Chemistry

2.1 Introduction

The growing demand for facile production of libraries of compounds in desirable amounts and sufficient purity for high-throughput screening (HTS) has presented challenging opportunities in the development of facilitated synthetic protocols which ultimately serve to uncover molecular leads as potential therapeutic agents aimed at improving human health. Arguably, the most effective advances realized in combinatorial chemistry during this past decade were those techniques that successfully integrated the sciences of organic synthesis and purification. Traditional solid-phase organic synthesis (SPOS), which encompasses several virtues and is based on a resin-platform, undoubtedly has been the primary driving force utilized to address this demand. While SPOS has its merits for offering a direct purification technique, and is highly amenable to automation, limitations have spurred the advancement of alternative platforms for use in the arena of facilitated synthesis.

In order to address these limitations, the last decade has seen a paradigm shift in the field whereby "the scaffold is returned" to solution and reagents/scavengers are immobilized.[1] Recent successes in solution phase, multi-step total syntheses championed by Ley and coworkers, utilizing exclusively immobilized reagents and scavengers,[2] whereby filtration was the sole purification protocol, are a testament to the power of this approach. Despite huge advances in this area, limitations in non-linear reaction kinetics, low resin-load capacities, means of distributing reagents, and the mechanics and technologies behind multi-step parallel solution phase sequences, continue to warrant the development of new platforms and improved strategies toward the ultimate goal of facilitating drug discovery.

This chapter highlights the latest developments and key advances in the application of scavengers in modern day synthesis. In particular, an emphasis is placed on the removal of excess reagents, intermediates and by-products to yield the desired products in high purity without the use of classical work-up procedures. While the focus of this chapter will be on the application of scavengers, the broader application of scavengers in library production and total synthesis has been highlighted. The overall aim is to showcase the application of both commercial and other types of available supported scavengers on a variety of tags across a range of methodologies.

Over recent years the aforementioned paradigm shift has driven the use of excess reagents to drive reactions to completion in order to expedite purification in the synthesis of large libraries of compounds. This itself has generated the need for an efficient process for the removal excess reagent to yield the desired product in high purity. Classical methods of purification such as aqueous extraction, chromatography, crystallization and distillation are time consuming and can be tedious procedures if run in a parallel fashion. In order to circumvent these problems a number of scavenging methods have emerged for the removal of excess nucleophiles, electrophiles, transition-metal catalysts and by-products. Scavengers meet this goal since they are highly effective at improving crude reaction purity and can be readily removed at the end of the reaction by simple filtration. A tagged scavenger has a functional group that is complementary to that of an excess reagent, thereby allowing the reaction between the two components. The scavengers can take advantage of both ionic and covalent interactions, and bind to the excess

reagent/byproduct. The tag then allows for purification via filtration eliminating the need for chromatography (Figure 2.1). Many of these scavengers are now available commercially for application across a wide range of synthetic methodologies in both academia and industry.

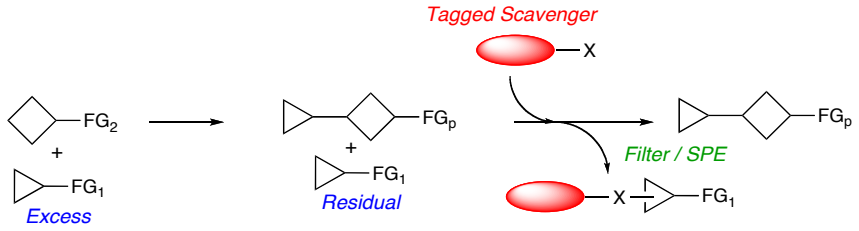


Figure 2.1

In the mid-90's, the importance of using scavengers in organic synthesis was addressed by a number of independent industrial research groups.[1] Pioneering work by Letsinger[3] and Merrifield[4] on solid phase organic synthesis provided the impetus for the rapid development and application of solid-phase methodology in the construction of large libraries. Reagents can be immobilized by tethering to either an insoluble or semi-soluble support material. Conventional supports are based on a divinylbenzene (DVB), cross-linked polystyrene resin, which can be micro- or macro porous depending on the cross-linking. Polystyrene-based resins have been the standard platform for immobilization of reagents and scavengers. However, in recent years, a number of different methods have emerged to address the issue of reaction kinetics, functional group load (mmol/g) and physical properties of the immobilization platform. These include, silica, fluorous, oligomeric, ionic, gel, dendrimer and magnetically-tagged reagents.

Electrophilic scavengers contain a reactive electrophilic functional group and hence have the capacity to react with a compatible nucleophile allowing for its sequestration and subsequent removal. Electrophilic scavengers are also referred to as nucleophile scavengers. A number of electrophilic/nucleophile scavengers have been developed to date and are summarized below.

Scavenger	Nucleophile scavenged
Isocyanate	Primary and secondary amines, alcohols, thiols
Acid chlorides/Anhydrides	Primary and secondary amines, alcohols, thiols
Aldehydes/Diketones	Primary amines, hydrazines
Sulfonyl chlorides	Primary and secondary amines, alcohols, alkoxides
Phosphonyl chlorides	Primary and secondary amines
Epoxides	Thiols and alkoxides
Triazene	Primary and secondary amines, alcohols, thiols
Diazonium salts	Primary and secondary amines

Nucleophilic scavengers contain a reactive nucleophilic functional group and hence have the capacity to react with a compatible electrophile allowing for its sequestration. Therefore these are also referred to as electrophile scavengers. A number of electrophile/nucleophilic scavengers have been developed to date and are summarized below.

Scavenger	Electrophile scavenged
Amine	Acids, Acid chlorides, sulfonyl chlorides
Thiol	Acid chlorides, sulfonyl chlorides
Alcohol	Acid chlorides, sulfonyl chlorides
Hydrazines	Aldehydes, Ketones
Diene	Dienophiles.
Dienophile	Diene

This chapter will will provide a brief discussion of scavengers aimed at the sequestration of nucleophiles as well as electrophiles and will be organized along the lines of the immobilization platform. A brief overview into their utilization in the production of libraries will also be discussed.

2.2 Polystyrene Resin Based Scavengers

Since the discovery of solid phase peptide synthesis in 1963,[4] the venerable polystyrene (PS) resin has remained the cornerstone of combinatorial chemistry over the years and continues to be utilized as the primary mode of support for immobilizing reagents and scavengers. This section will briefly outline the latest developments of resin-based scavengers.

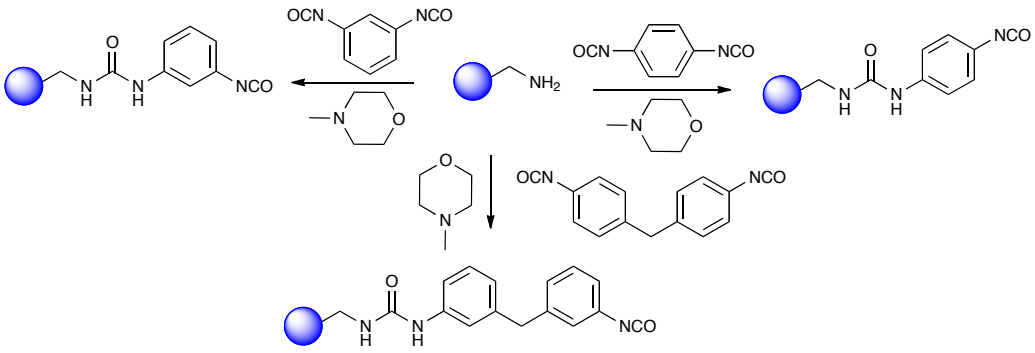
2.2.1 PS-Based Supported Isocyanates

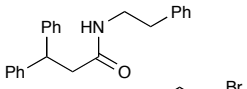
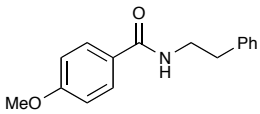
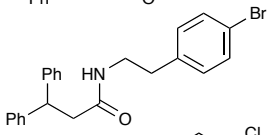
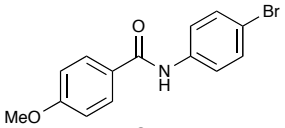
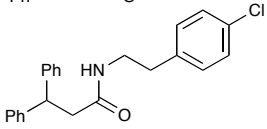
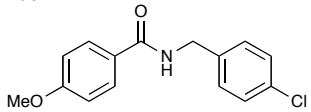
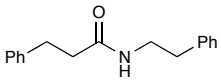
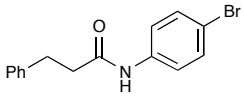
Isocyanates have traditionally been a highly utilized amine scavenger. Kaldor and coworkers first reported the polystyrene-based isocyanates,[1c] since this publication, a number of supported isocyanates have appeared in the literature. Among these, Bradley and coworkers have developed a number of resin bound isocyanates.[5] In their work, a macro porous resin-bound isocyanate was produced via the reaction between para-diisocyanate (PDI) and a macro porous amino resin. The resin was optimized for maximum swelling (prepared with 40% cross linking and 300% porogen level in toluene) and was reported to be more reactive than commercially available polystyrene amino methyl isocyanate resins.

Bradley and co-workers next reported the synthesis of an array of supported isocyanates using three different commercially available diisocyanates and the optimally prepared macro porous resin mentioned above. In addition, they employed a gel resin obtained from commercial sources (Scheme 2.1). Compared to the commercially available resins, the Bradley scavengers were found to have higher reactivity and to display better reaction kinetics. They have been utilized to scavenge

amines in a pilot library of DCC-mediated amides, whereby excellent results were achieved in scavenging the residual amines .

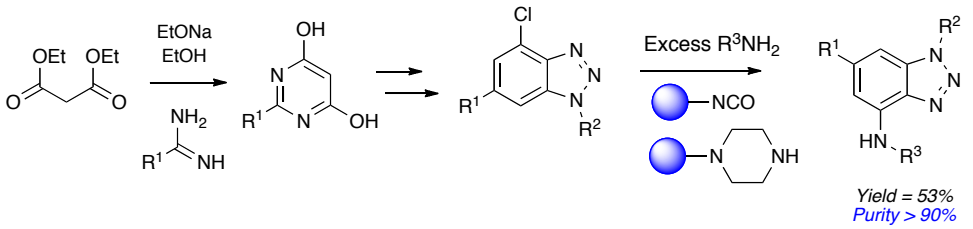
Scheme 2.1



Amide product	Amine scavenged (%)	Amide product	Amine scavenged (%)
	100		100
	100		100
	56		100
	100		100

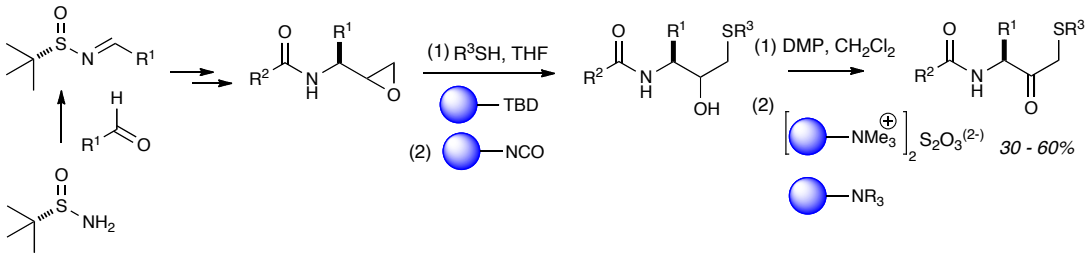
Conventional polystyrene isocyanates have been successfully utilized for nucleophile scavenging in the synthesis of pharmaceutically attractive molecules. Player and coworkers recently have reported the use of conventional resin-bound isocyanates in the scavenging of amines in the synthesis of an 80-member library of triazolo-pyrimidines with purities greater than 90% (Scheme 2.2).[6]

Scheme 2.2



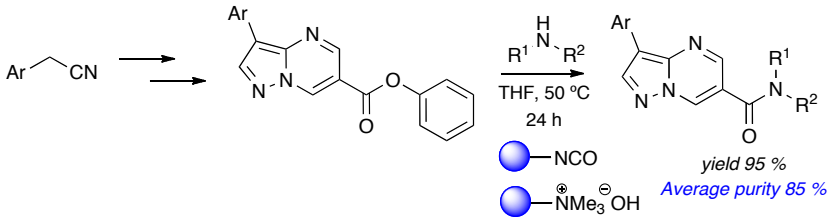
Ellman and co-workers have also reported the use of these resin-bound isocyanates for the scavenging of thiols in the parallel synthesis of a small library of cysteine protease inhibitors (Scheme 2.3).[7] Simple filtration afforded the hydroxy sulfide products in moderate to good yields. Excess Dess-Martin periodinane, as well as the by-product in the final step, were scavenged using a resin-bound thiosulfate to yield target compounds.

Scheme 2.3



In a recent report, Gregg and coworkers outline the use of conventional resin-bound isocyanates in scavenging amines for the synthesis of a large library of aryl pyrazolo pyrimidine carboxamides (Scheme 2.4). A variety of primary as well as secondary amines were utilized in the amidation of activated nitro phenyl ester. Subsequent scavenging of amines with polystyrene isocyanate afforded the target compounds with purities greater than 85% over a range of 426 compounds (more than 90% of library population). [8]

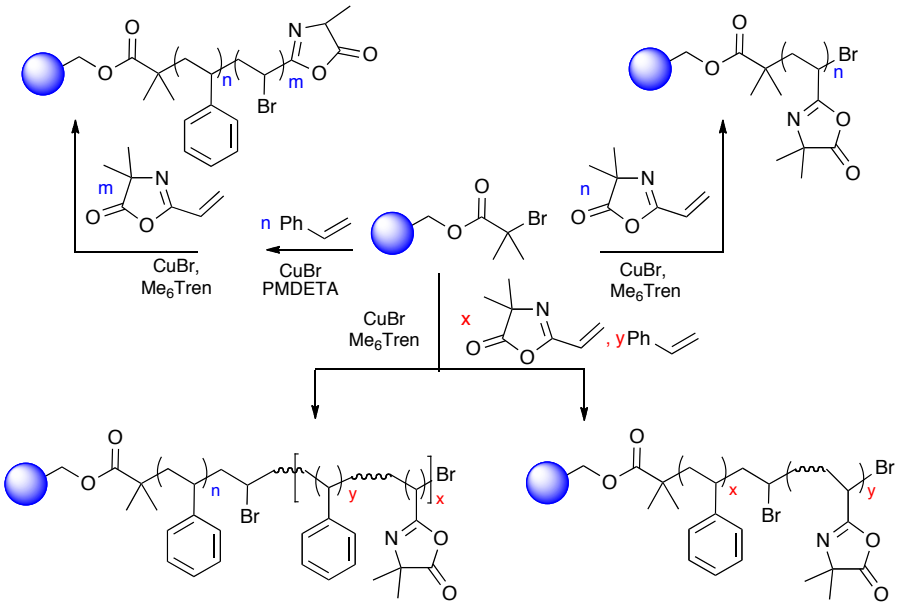
Scheme 2.4



2.2.2 PS-Based Supported Anhydrides and Acid chlorides

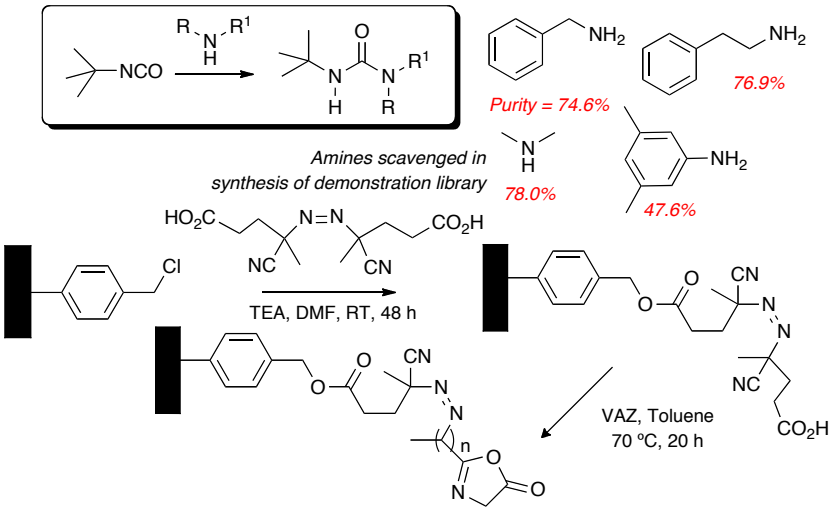
Fontaine and coworkers have recently reported the synthesis of a supported aza-lactone via atom radical transfer polymerization (ATRP).[9] This method involved the preparation of a Wang resin-supported initiator, followed by subsequent ATR polymerization between 2-vinyl-4, 4-dimethyl-5-oxazolone and styrene to generate several macro porous, aza-lactone functionalized resins with different architectures. These were shown to scavenge benzyl amines in a highly efficient fashion (Scheme 2.5).

Scheme 2.5



Fréchet and coworkers have reported the development of a functionalized polymer monolith for use in parallel solution phase synthesis in continuous flow applications.[10] In this report, the authors outline the preparation of an azalactone-functionalized polymer monolith for scavenging nucleophiles. This method involves the preparation of a macro porous poly(chloromethylstyrene *co*-divinylbenzene) monolith via the polymerization of the relevant mixture of monomer, initiator and porogen. The chloromethyl groups at the pore surface are allowed to react with a free radical initiator (4-cyanovaleric acid), followed by subsequent reaction with 4-vinyl-2,2'-dimethylazalactone (VAZ) to provide an azalactone-functionalized monolith. These monoliths were then demonstrated to completely remove amines after flowing a solution of amine in THF through the monolith for 30 minutes. They have also reported the reaction of these monoliths with alcohols as well. A small demonstration library of urea's were prepared and after 8 minutes of residence time up to 76% of the alkyl amines were found to be scavenged by the monolithic azalactone (Scheme 2.6).

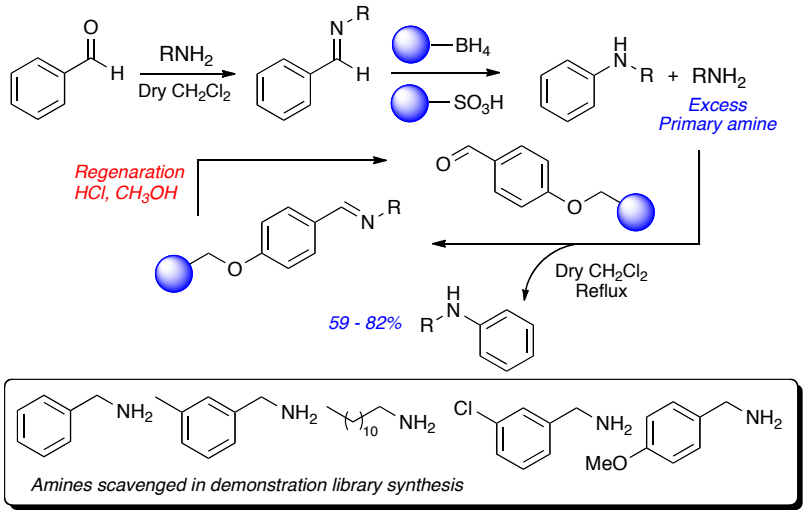
Scheme 2.6



2.2.3 PS-Based Supported aldehydes

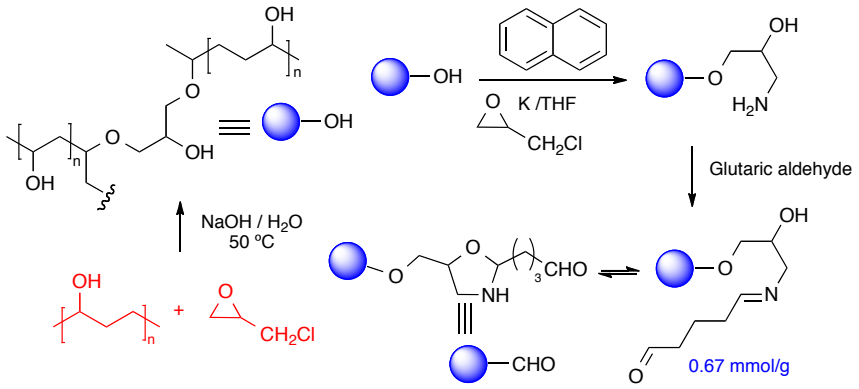
Kaldor and others first reported resin-bound aldehydes[11] for the scavenging of amines. Recently, Miguel and coworker investigated the use and recycling of polystyrene-supported benzaldehyde in amine scavenging.[12] The PS-benzaldehyde has been found to be amenable to 3 reaction cycles with the corresponding yields being maintained throughout. It was also found that these scavengers sequestered primary amines over secondary with remarkable selectivity (Scheme 2.7).

Scheme 2.7



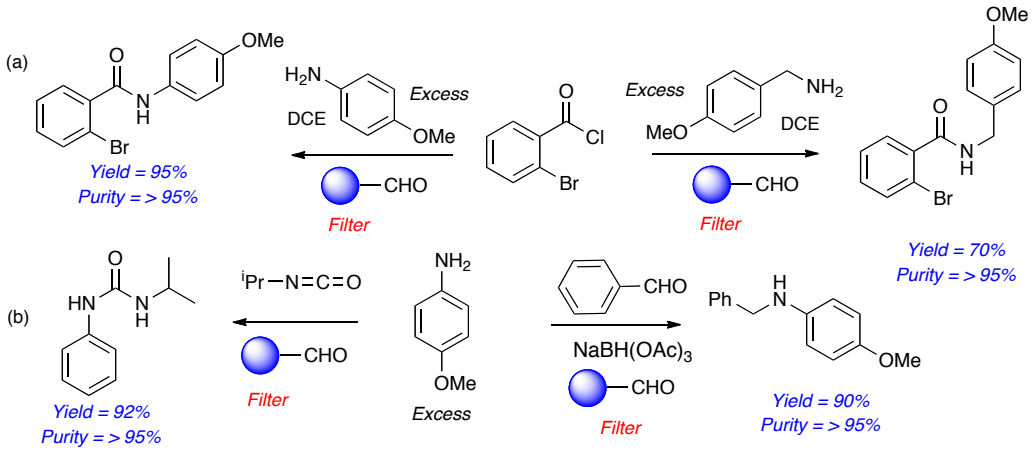
Zhu and coworkers have reported the synthesis of functionalized polyvinyl alcohol resins for use as scavengers.[13] This was achieved via inverse suspension polymerization along side epichlorohydrin as a cross linker. These resins were found to have excellent swelling characteristics in DMF, CH_3OH, dioxane, THF, CH_2Cl_2 and H_2O. These were then functionalized with glutaric aldehyde to provide a polymer-supported aldehyde (Scheme 2.8).

Scheme 2.8



This polymer-supported aldehyde was found to scavenge both alkyl as well as aryl primary amines over secondary amines and exhibit remarkable facility in the synthesis of a demonstration library of amides, ureas and secondary amines (Scheme 2.9).

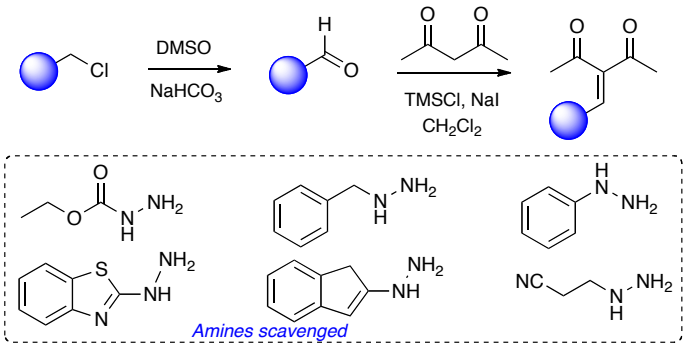
Scheme 2.9



2.2.4 PS-Supported Diketones

Kirschning and coworkers have recently reported the synthesis of a resin-bound diketone for the sequestration of amines and hydrazines.[14] The synthesis of the resin-bound diketone was achieved via oxidation of a chloromethyl resin, followed by reductive coupling with 2,4-pentadione, to provide the requisite scavenger resin. This resin was found to be more efficient than supported-aldehydes for amine and hydrazine scavenging and furthermore, found to be selective for the scavenging of primary amines over secondary amines (Scheme 2.10).

Scheme 2.10

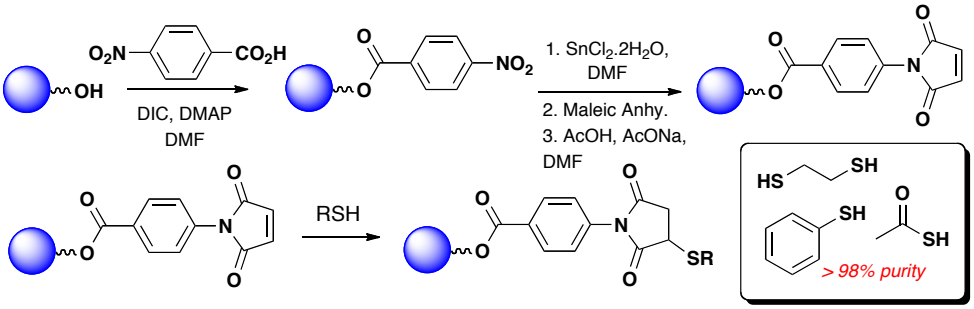


2.2.5 PS-Supported Maleimide

Maleimide is a well-known Michael acceptor, dienophile and dipolarophile and hence is another versatile functional moiety that has found multiple uses in combinatorial chemistry as both a scavenger as well as a template in library synthesis.[15] Barrett[16] and Porco[17] have both reported the synthesis of a polystyrene resin-supported maleimide but did not report its use in the scavenging of nucleophiles. Hall and coworkers recently described the synthesis of a supported-maleimide reagent for the library synthesis of functionalized pyrollidines via a [3+2]

cycloaddition. The reagent is synthesized via the esterification of *p*-nitrobenzoic acid with both Rink and Sasrin resins, followed by reduction of the nitro group and subsequent condensation with maleic anhydride. This resin was found to have a remarkable ability to scavenge alkyl as well as aromatic thiols (Scheme 2.11).[15]

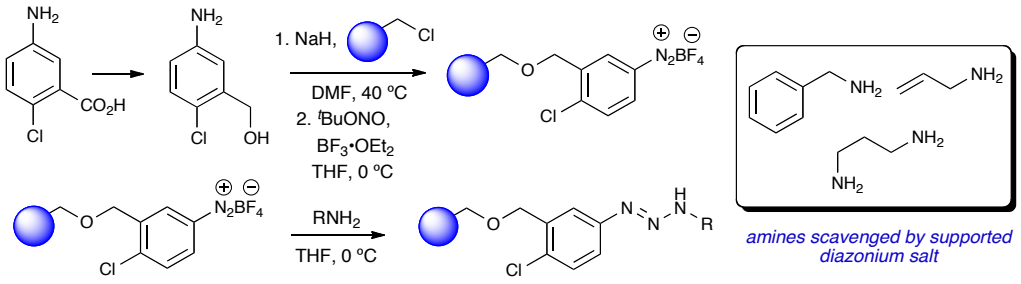
Scheme 2.11



2.2.6 PS-Supported Diazonium salts

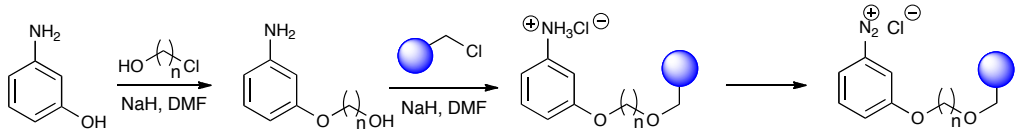
Bräse and coworkers were the first to introduce triazene linkers for use in SPOC in a seminal report in 2000.[18] They found immobilized diazonium ions have high stability, which enabled their application as linkers and scavengers. Their synthesis involves the reduction of *p*-amino benzoic acid, which was subsequently coupled onto a Merrifield resin via standard etherification. Subsequent conversion of the amino group to a diazonium salt generated the supported diazonium tetrafluoroborate, which was found to sequester amines (Scheme 2.12).

Scheme 2.12



In related work, Lazny and coworkers report a new economical synthesis of four new polymeric supports with 3- and 6-carbon atom spacers and triazene linkers derived from *meta*- and *para*-aminophenol. In addition to their use as supports for immobilization of secondary amines, they were shown to be capable of scavenging amines (Scheme 2.13).[19]

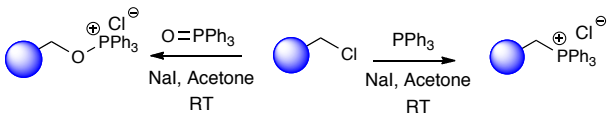
Scheme 2.13



2.2.7 Resin-Supported Halide

Lipschutz and coworkers have recently reported the use of modified, conventional Merrifield resin for scavenging both PPh_3 and $O{=}PPh_3$ in transition metal-catalyzed cross coupling reactions (Scheme 2.14).[20] The modified resin was produced by reacting commercially available, high-load, chloromethylated polystyrene, in situ with NaI, to produce a more reactive iodo-Merrifield resin, which participated in facile removal of both PPh_3 and $O{=}PPh_3$.

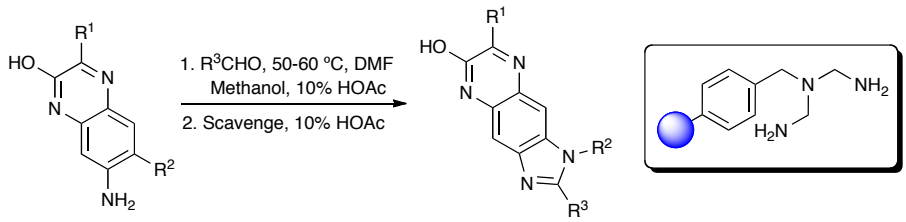
Scheme 2.14



2.2.8 PS-Supported Amine

Amine scavengers have been one of the most developed and widely used to remove a range of electrophiles on a number of different platforms. Traditionally developed on a polystyrene bead, amine scavengers have been utilized in natural products or library synthesis to yield high purity via a facilitated protocol. In 2005, Liu reported the use of a polystyrene-bound amine scavenger for the removal of excess aldehydes to provide imidazole derivatives in high purity without the need for classical purification (Scheme 2.15).[21]

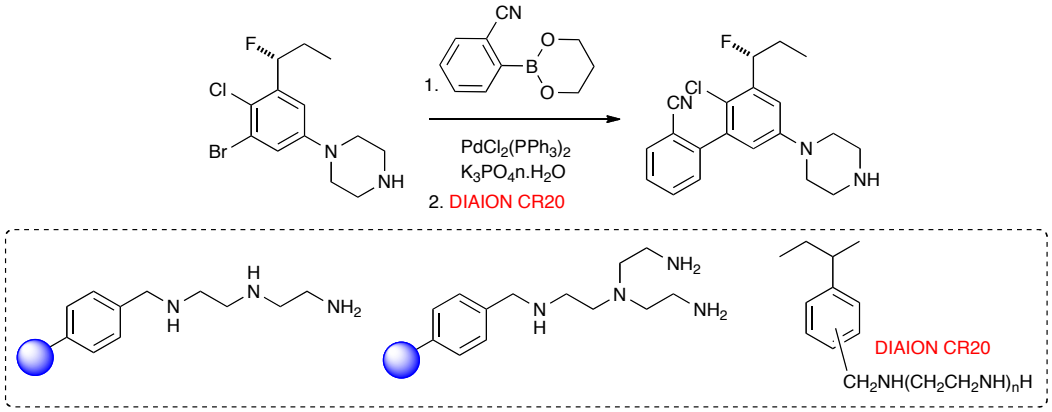
Scheme 2.15



Palladium-catalyzed organic synthesis has been utilized throughout the pharmaceutical industry, taking advantage of its C-C bond formation capability. However the issue of residual levels of palladium has been a major concern due to its ability to attentuate biological screens. To address this, a number of scavengers were developed and applied for the removal of residual palladium. One such example was reported by Ogura who demonstrated a range of polymer-bound ethylene diamines as scavengers of both palladium (0) and (II) species.[22] The levels of residual palladium

from the Suzuki-Miyaura coupling were reduced from 2000-3000 ppm to 100-300 ppm by application of these scavengers. Additionally, a commercial available chelating resin DIANON CR20 was evaluated and gave comparable results as the polymer-bound scavengers (Scheme 2.16). However, longer reaction time was needed to obtain comparable results using equivalent loadings of DIANON CR20.

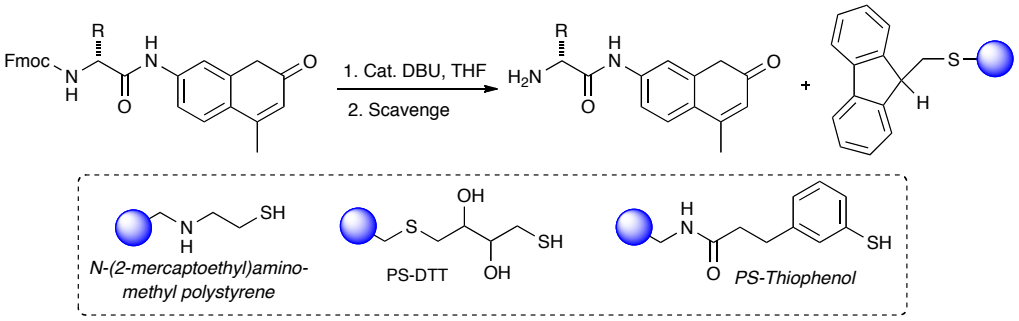
Scheme 2.16



2.2.9 PS-Supported Thiols

Hong reported a simple protocol for the removal of 9-methylene-9*H*-fluorene, a by-product in the deprotection of Fmoc-protected amines.[23] A number of thiol-containing polystyrene resin scavengers were utilized to remove this by-product in a mixture with DBU and product (**Scheme 2.17**). This methodology provided an efficient procedure for the removal of Fmoc groups yielding amines in high purity without the need for chromatography.

Scheme 2.17

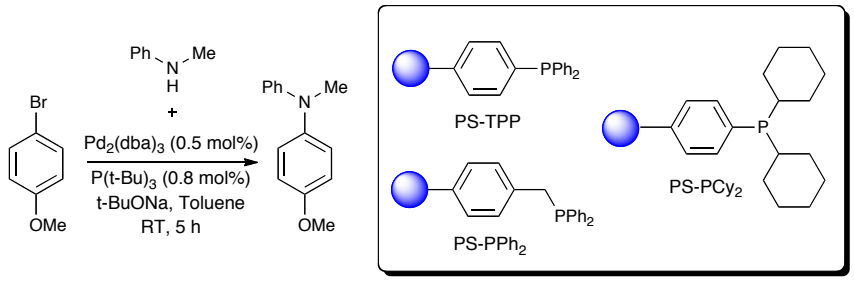


2.2.10 PS-Supported Phosphines

In a similar fashion, efforts for the development and application of supported phosphines as scavengers to remove a variety of electrophiles have been reported. Reports demonstrate the diversity of resin-tags used, and their applications as both supported reagents and scavengers.[24] Hii reported the application of three phosphine-functionalized polymers as effective scavengers of palladium.[25] Notably, the most effective was an inexpensive and commercially available PS-PPh_2 which gave the desired products in purity of >98.5 % by ICP-AES analysis (

Scheme 2.18).

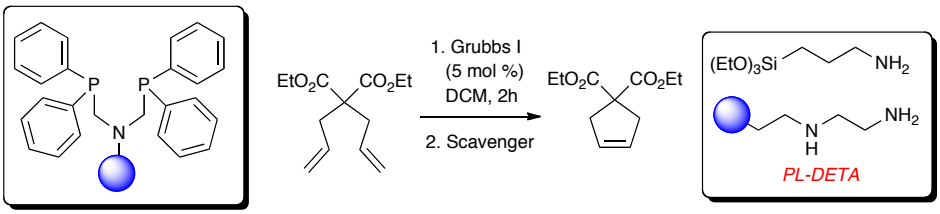
Scheme 2.18



As previously described in the residual removal of palladium, the residual presence of other metals from catalysis has also been an area of concern. The emergence of the ruthenium-based Grubbs catalyst has led its application in the

synthesis of complex natural products and libraries. The removal of residual catalyst from product, however, has remained a problem. One approach to circumvent this problem was reported by Breinbauer who scavenged residual ruthenium using an inexpensive polymer-bound chelate phosphine.[26] Scavenging of crude mixtures removed ruthenium to give the desired product in >95 % purity (Scheme 2.19).

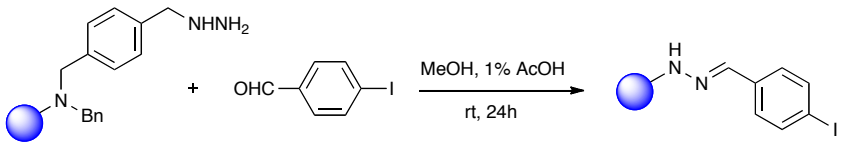
Scheme 2.19



2.2.11 PS-Supported Hydrazines

Wessjohann reported the application of a polymer-supported benzylhydrazines as a reversible scavenger resin for aromatic aldehydes.[27] These "protected aldehydes" can undergo additional transformations and eventually be released to either reveal the original aldehyde functionality or be released in a diversification step (Scheme 2.20).

Scheme 2.20



2.3 PEG-Supported scavengers

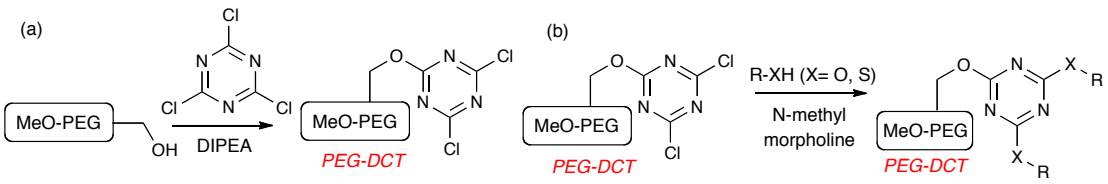
In spite of the aforementioned successes, resin-bound reagents and scavengers still suffer from slow reaction kinetics due to heterogeneity, as well as low load levels of traditional resins. These deficiencies have prompted the continued development of

alternate platforms for facilitating synthesis. One such platform is the use of polyethylene glycol (PEG)-supports, which was pioneered by Janda and coworkers. PEG-supports have emerged as an attractive alternative since they address a key weakness of their traditional polystyrene-bound counterparts in that they are soluble polymers,[28] and hence react under homogenous conditions improving reaction kinetics. Once the reaction is completed, they are precipitated and filtered away from the desired products. Traditionally, Et_2O and hexanes are the solvents of choice for precipitating PEG-based supports.

2.3.1 PEG-Supported Dichlorotriazene (DCT)

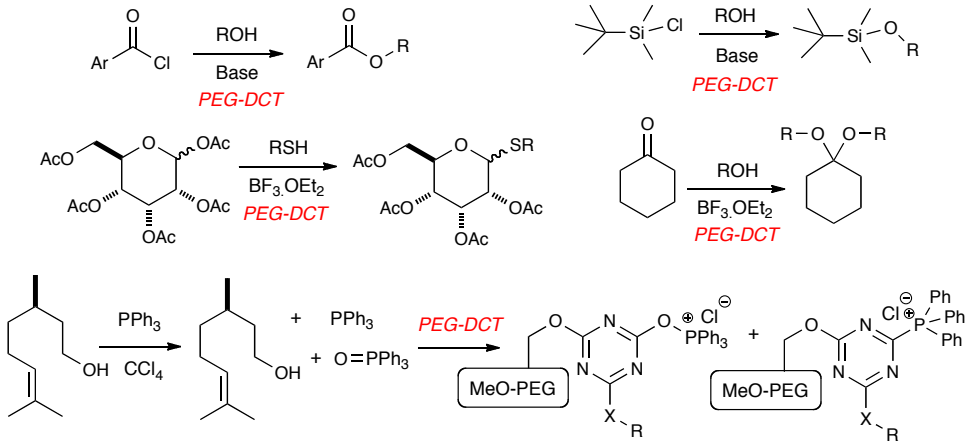
Trichlorotriazene is a well-known versatile reagent in organic synthesis and has been utilized to facilitate a number of different reactions.[29] Due to its highly electrophilic character it reacts readily with nucleophiles and is therefore eminently suitable for scavenging nucleophiles. Taddei and coworkers first reported a polystyrene resin-bound dichlorotrazene (DCT) as a coupling agent for amide synthesis.[30] They also published a subsequent report on the development of a PEG-supported DCT reagent.[31] The reagent was readily prepared by simple condensation of trichlorotriazine with MeO-PEG-OH to provide the soluble PEG-DCT reagent (Scheme 2.21).

Scheme 2.21



The soluble PEG-DCT reagent was utilized to scavenge alcohols in the synthesis of esters and silyl-protected alcohols as well as acetals, and thiols in the synthesis trans-glycosylated carbohydrates with high efficiency. They also reported the sequestration of triphenyl phosphine and triphenyl phosphine oxide by this PEG-supported DCT reagent (Scheme 2.22). Since this report by Taddei, there have been a number of developments pertaining to support DCT for the scavenging of nucleophiles.

Scheme 2.22

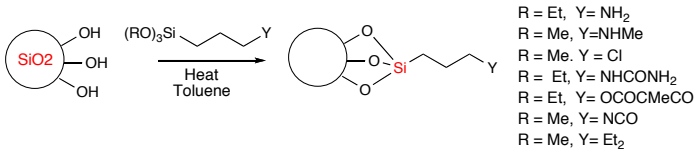


2.4 Silica-Supported Scavengers

Silica has recently surfaced as an alternative support for the immobilization of reagents and scavengers due to several attributes. A key feature is that reaction kinetics are higher than in conventional resins, due to the fact that functional groups lie on the surface and hence are not embedded and thus limited by diffusion rates. In addition, silica is compatible with a range of solvents (polar and non-polar), while maintaining its insolubility, as a consequence of its non-swelling nature. Moreover, the free flowing nature of silica allows for easy handling while its mechanical

stability allows for conventional methods of stirring Si-supported reagents.[32] Woodward and co-workers recently reported the synthesis of Si-bound reagents and Si-grafted pellets; among these was a Si-supported isocyanate. The Si-supported isocyanates were not employed in scavenging, but are now commercially sold for that use (Scheme 2.23).[33]

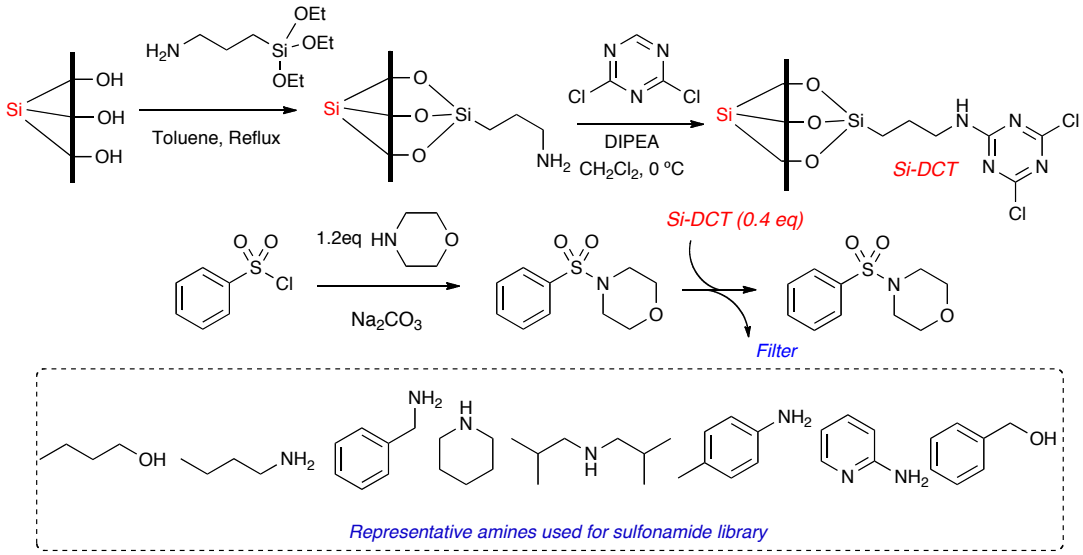
Scheme 2.23



2.4.1 Silica-supported DCT

Recently Pattarawarapan and coworkers reported the synthesis of a Si-supported DCT for scavenging nucleophiles.[34] 3-Aminopropyltrimethoxysilane was allowed to react with commercial silica gel in toluene. TCT was then reacted with the Si-immobilized amine to provide the supported DCT reagent. This was found to sequester both amines (primary and secondary) as well as alcohols with remarkable facility and two libraries of sulfonamides and amides were prepared in parallel format. Filtration was the sole purification step (Scheme 2.24).

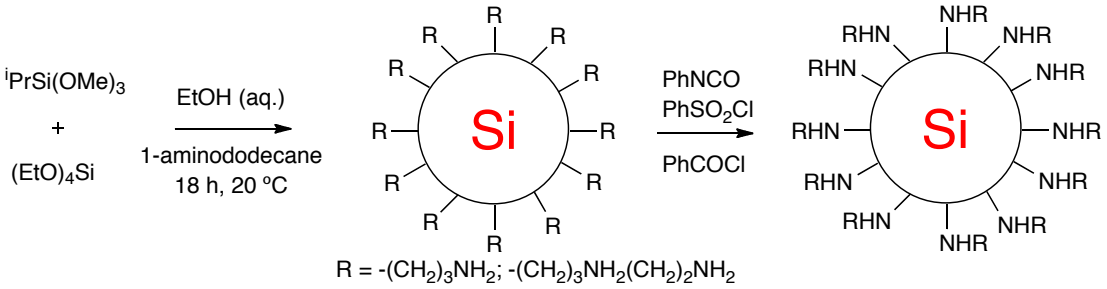
Scheme 2.24



2.4.2 Silica Supported Amines

As stated above, silica tags have seen increased use in the field of solid-phase synthetic chemistry, with amine resins specifically being a major contributor to the development and advancement of this immobilized tag. Rousseau reported the application of high-load amino and diamino functionalized mesoporous silica as a highly effective scavenger of sulfonyl chlorides, aromatic isocyanides and acid chlorides.[35] Synthesis of this scavenger is based on the condensation of propyltrimethoxysilanes with tetraethoxysilane leading to highly functionalized scavengers (Scheme 2.25). Unlike polystyrene-tagged amine scavengers, these Si-tagged scavengers have demonstrated a range of solvents while maintaining scavenging load.

Scheme 2.25



Acylation and benzylation reactions are two of the most common reactions for diversification of core scaffolds. To counteract the use of excess acylating reagents, a number of scavengers have been developed and used in the facilitated synthesis of acylated compound libraries. In 2003, Khmelnitsky reported the efficient removal of excess acyl donors following enzymatic acylations.[36] Scavenging was accomplished with a variety of commercially available amino-functionalized scavengers tagged on both silica and polystyrene resins (Figure 2.2). These scavengers can be applied to a wide variety of electrophilic donors revealing a highly efficient method of acyl scavenging, affording the acylated product in high yield.

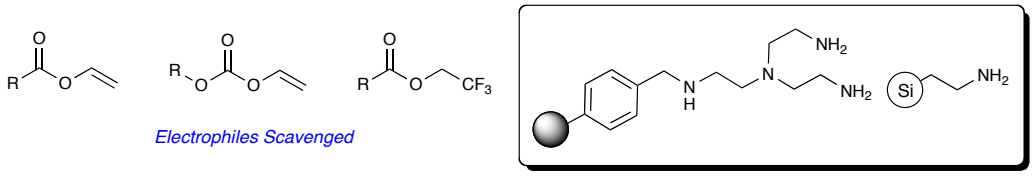


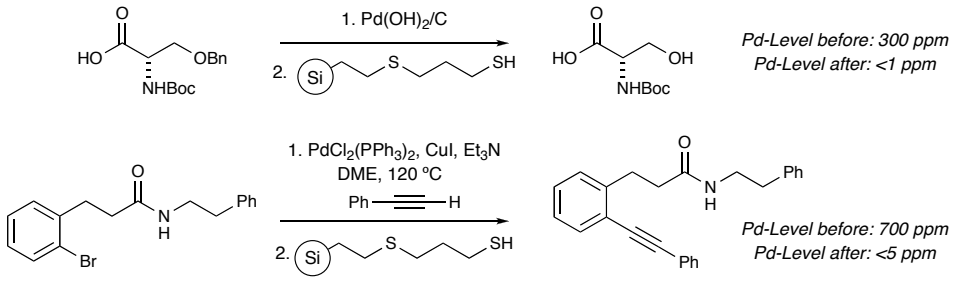
Figure 2.2

2.4.3 Silica-Supported Thiols

In 2007, Wilson reported the application of highly functionalized, multidentate thiol-based Si-supported scavenger for the removal of palladium species from active pharmaceutical ingredients.[37] The removal of palladium from numerous types of reactions was demonstrated including protective group removal, as well as

removal from Suzuki, Heck, and Buchwald-Hartwig coupling reactions. Scavenging was achieved at room temperature to reduce levels of palladium to below 5 ppm (un-optimized). Furthermore, these Si-based scavengers had broad solvent compatibility, stability, ease of handling, and application to large-scale synthesis (Scheme 2.26).

Scheme 2.26



2.5 Fluorous-Tagged Scavengers

Fluorous-tagged reagents and scavengers championed by Curran, Zhang and others have gained much prominence over the last few years.[38] Fluorous tagging does not involve the use of conventional resin beads, but entails the attachment of a perfluoroalkyl tag to a reagent. Both heavy fluorous tags (60% or more fluorine by weight) as well as light fluorous tags (40% or less fluorine by weight) are utilized in this process. Workup involves the use of liquid-liquid extraction for the separation of fluorous and non-fluorous substances (heavy fluorous tags) or fluorous silica gel-based solid phase extraction (light fluorous synthesis). Since fluorous silica gel has a bonded phase of C_8F_7 perfluorohydro carbon chains, it retains fluorine-containing molecules via the strong fluorine-fluorine interactions. Since resins are not involved, all chemistry takes place in solution phase allowing for the utilization of normal reaction conditions with minimal of optimization time, and increased reaction kinetics

over conventional resin-bound chemistry.[39] Fluorous tags are chemically inert and hence do not partake in any side reactions with exogenous reactants. These features, coupled with their simple preparation, scale-up, and adaptability to automation, have elevated fluorous-tagged scavengers and reagents as highly attractive tools for both traditional and high throughput chemistry.

2.5.1 Fluorous-Tagged Anhydrides and Isocyanates

Zhang and coworkers developed the use of fluorous-tagged isocyanate as well as isatoic anhydride and acid chloride for the scavenging of amines for use in combinatorial as well as conventional chemistry (Figure 2.3).[40] All reagents were readily prepared from commercially available sources, and the F-isatoic anhydride was prepared via a simple NaH-mediated alkylation of isatoic anhydride with perfluoroalkyl halide.

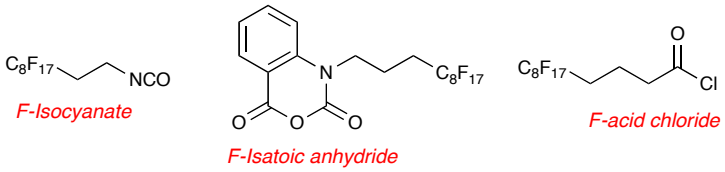
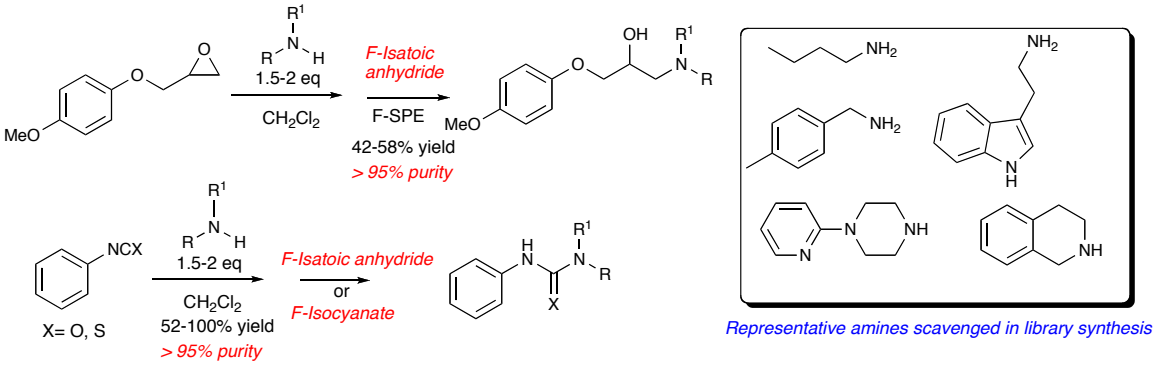


Figure 2.3

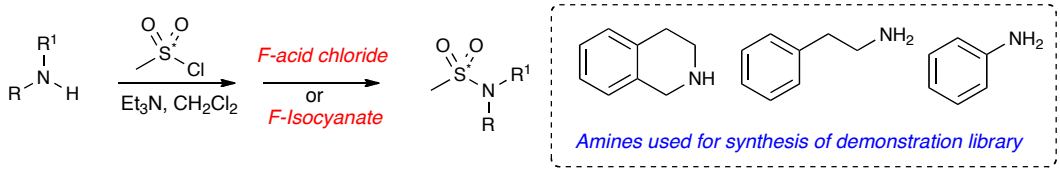
Zhang and coworkers elegantly demonstrated the use of F-isocyanates as well as F-isatoic anhydrides in the synthesis of a library of amino alcohols (via amine ring opening of glycidyl epoxide ethers) and a library of ureas and thioureas. Purities were reported to be in excess of 95%, while yields were slightly better when the anhydride was used (Scheme 2.27).

Scheme 2.27



Zhang and co-workers workers demonstrated the use of F-acid chlorides alongside the concurrent use of the corresponding conventional resin-bound scavengers in the synthesis of a small library of sulfonamides with both primary as well as secondary amines. Scavenging was almost complete (< 2% amine remained) with the use of F-acid chlorides, while a substantial amount remained in the use of resins. After 24 hours, amines were scavenged by the fluorous reagents, while 3-12% amines remained unquenched when resins were used (Scheme 2.28).[41]

Scheme 2.28



2.5.2 Fluorous-Tagged Sulfonyl chlorides and Acid chlorides and Epoxides.

Lindsay and coworkers have reported the synthesis of a suite of fluorous-tagged scavengers for parallel solution phase synthesis (Figure 2.4).[42]

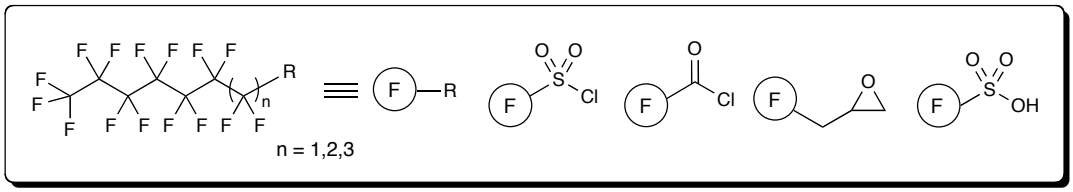
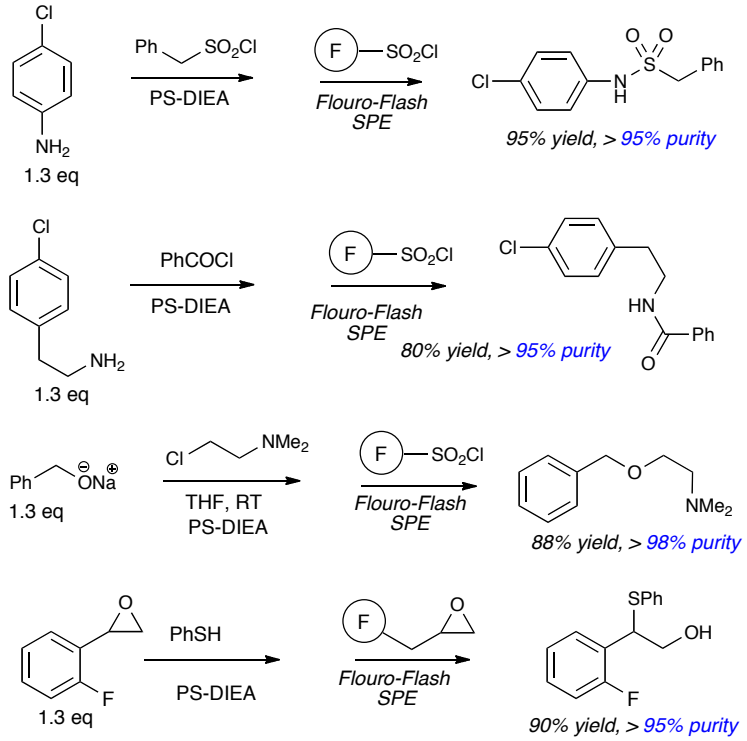


Figure 2.4

These scavengers have been applied towards the synthesis of a variety of libraries in high efficiency and exceptional purity (>96%). Of particular note is their use of a tagged-epoxide for removal of alkoxide and thiols (Scheme 2.29).

Scheme 2.29

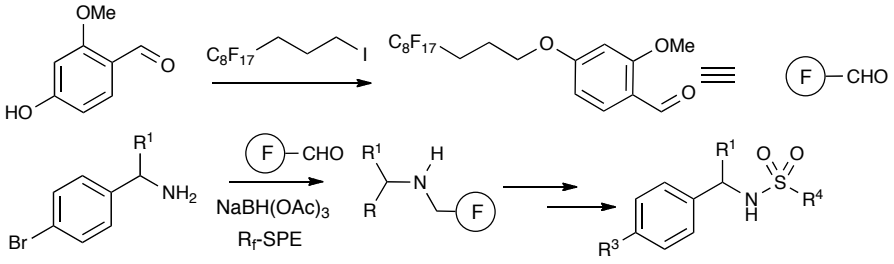


2.5.3 Fluorous-Tagged Aldehyde

Ladlow and coworkers have reported the use of fluorous-tagged aldehydes as a protecting goup in the synthesis of a library of sulfonamides. The F-aldehyde was prepared via a simple alkylation of 4-hdyoxy-2-meoxybanzaldehyde with a

perflouroalkyl halide. The authors have protected a variety of primary amines with the F-aldehyde followed by reduction, sulfonylation and Suzuki coupling and acid-mediated deprotection. Filtration via a fluorous SPE was the sole mode of purification (Scheme 2.30).[43] Although the authors have not reported the use of the F-aldehyde for amine scavenging, the aforementioned results point toward the promise of this reagent for scavenging amines in parallel synthetic protocols.

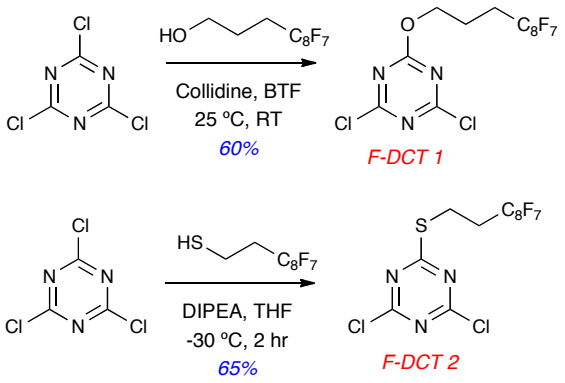
Scheme 2.30



2.5.4 Fluorous-Tagged DCT

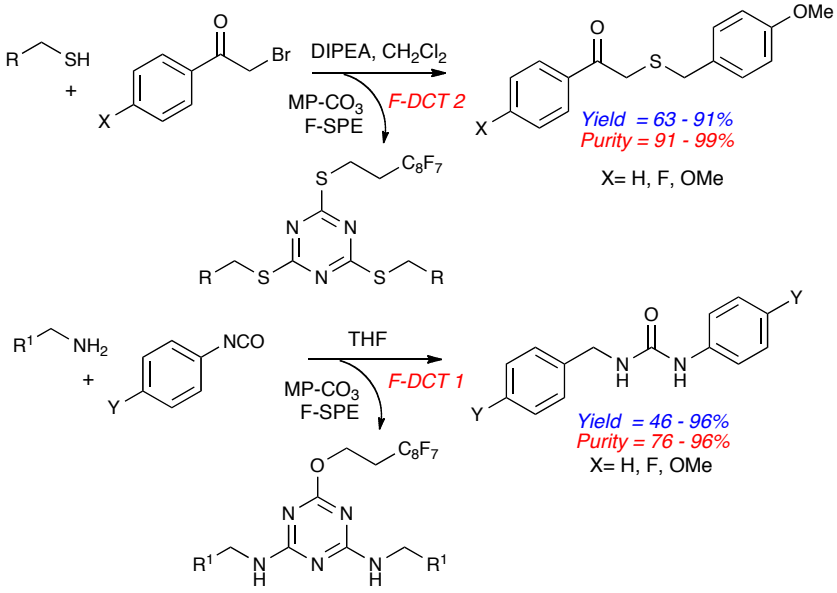
Zhang and coworkers have reported the synthesis of two fluorous DCT reagents for parallel synthesis. TCT was allowed to react with a fluorous-tagged alcohol as well as a fluorous-tagged thiol to produce the two reagents shown in Scheme 2.31.[44]

Scheme 2.31



These reagents were utilized in the usual fashion to scavenge thiol as well as amines in the synthesis of a library of sulfides and amides with a high degree of purities and yields (Scheme 2.32). A significant feature of this approach was the purification utilizing plate-to-plate fluorous SPE as well as an automated solid phase extraction on a RapidTrace® system thus demonstrating the capacity of fluorous platforms for automation.

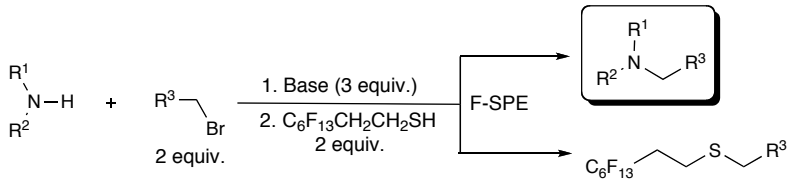
Scheme 2.32



2.5.5 Fluorous-tagged Thiols

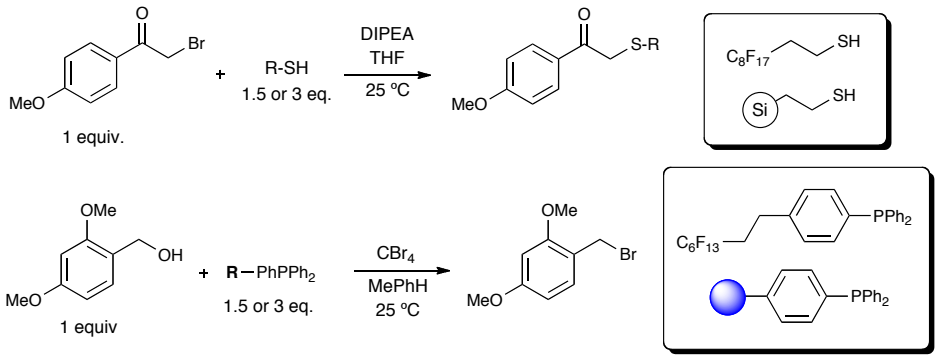
Like amine scavengers, Chen described the application of a commercially available fluorous-tagged thiol scavenger for the removal of alkylation reagents.[45] A range of tertiary amines was synthesized via alkylation using excess *a*-bromoketones/benzyl bromides (Scheme 2.). The desired compounds were isolated by scavenging excess reagent, and separation of the product from the scavenger was achieved by solid phase extraction on fluorous silica gel.

Scheme 2.33



Like Kappe in 2003, Zhang in 2005 reported a kinetic study for the evaluation of fluorous-tagged scavengers with their polystyrene resin counterpart.[46] Kinetic studies were undertaken for both the fluorous-tagged thiol as a scavenger for *a*-bromoketones and the fluorous-tagged triphenylphosphine used in bromination of alcohols (Scheme 2.34). When the reactions were carried out involving fluorous-tagged scavengers, the reactions were homogenous providing solution-phase reaction kinetics. However, scavengers tagged with a solid-support were heterogeneous, and the reaction kinetics was greatly affected by the nature of the solid-support and the reaction environment. Overall, significantly greater amounts of scavenger and more time were required when using a solid-supported scavenger.

Scheme 2.34



2.6 ROMP-Derived Scavengers

Soluble polymers[28] and scavenger resins have emerged as a means of utilizing solution phase reaction kinetics with all the advantages of their solid phase counterparts. In the course of these developments, pioneering work by Barrett and coworkers,[47,48] led to the general use of ring-opening metathesis (ROM) polymerization for generating high-load, immobilized reagents. Reagent generation involves the polymerization of strained functionalized norbornenyl-tagged functional groups catalyzed by Grubbs ruthenium alkylidene metathesis catalysts (Figure 2.5).[49] In most cases, norbornenyl-derived cross-linkers were employed to enhance swelling properties and insure insolubility. Occasionally, the polymeric backbone was hydrogenated, using Wilkinson catalyst under high pressure. Barrett's seminal 2002 review[47] discusses a wide variety of ROMP-gel supported reagents.

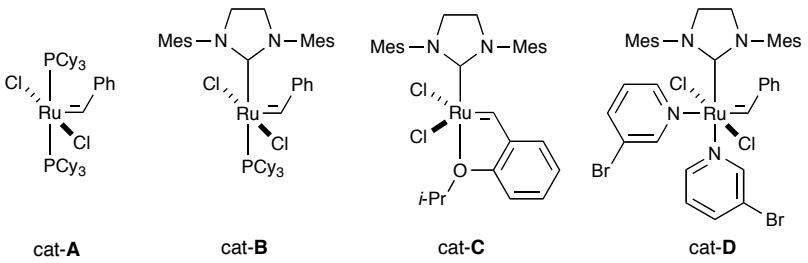
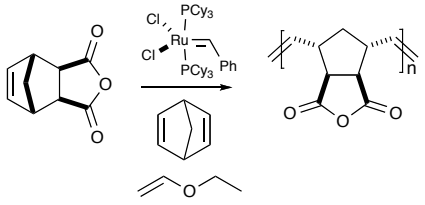


Figure 2.5

2.6.1 ROMP-Gel Anhydride

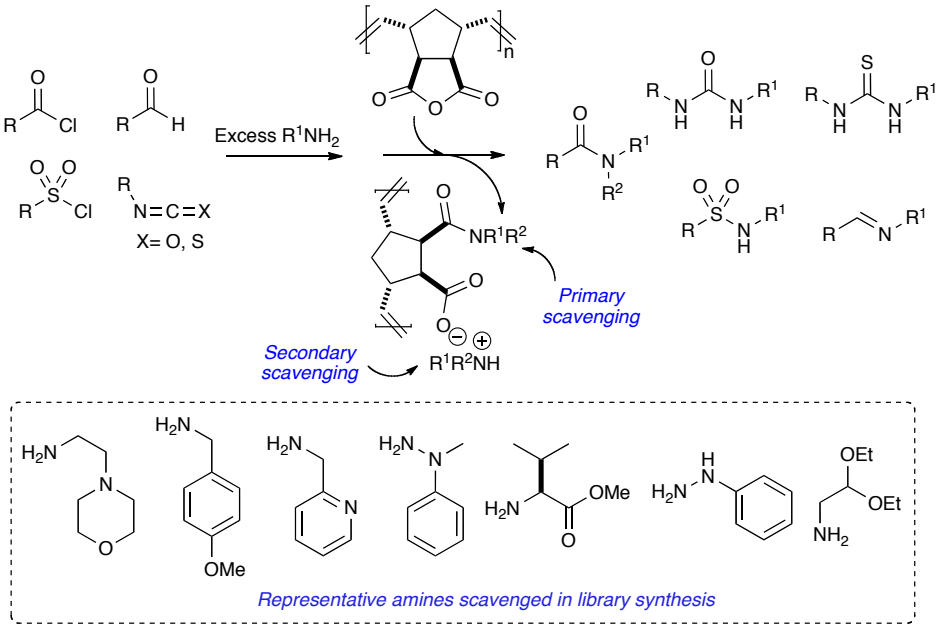
Barrett and coworkers reported the use of ROM polymerization in the synthesis of a supported anhydride for nucleophile scavenging.[50] The norbornenyl-tagged monomer can either be bought commercially or prepared via a simple Diels-Alder reaction. Polymerization is then carried out in the presence of the Grubbs first-generation ruthenium alkylidene catalyst[49] in the presence of a cross-linking agent (norbornadiene) to produce a ROMP-gel possessing exceptionally high load capacity (Scheme 2.35).

Scheme 2.35



Barrett and coworkers found that the ROMP-gel anhydrides efficiently scavenge a variety of amines as well as alcohols with high efficiency and purity (Scheme 2.36).

Scheme 2.36



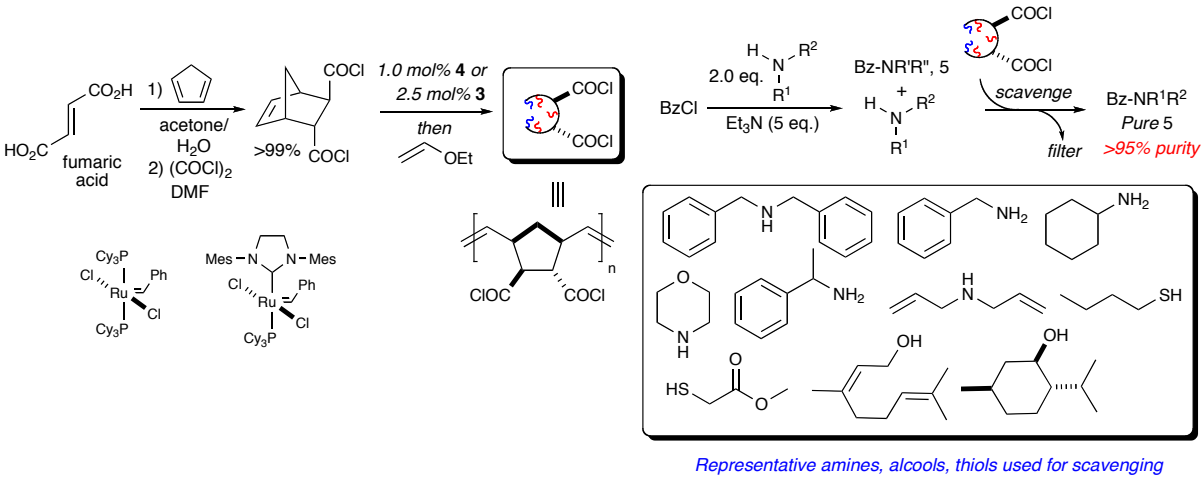
Hanson and coworkers recently reported the synthesis of a number of high load reagents via ROM polymerization techniques to provide supported reagents possessing solubility profiles that are tunable and which can be used in parallel solution phase synthesis. These high load reagents are generated by the ROM polymerization of norbornene- or 7-oxonorbornene-based monomers employing different Grubbs catalysts (Figure 2.5) to produce oligomers of varying lengths and solubility profiles. The diverse solubility profile of these reagents allows reactions to be conducted in common reaction solvents such as DCM, THF, DMF and $CHCl_3$. Following reaction/transformation, precipitation with an appropriate solvent (Et_2O, MeOH, or EtOAc), followed by filtration, provides products in good to excellent yields and purities. Noteworthy, is precipitation with EtOAc providing a wider solubility profile; a crucial feature in producing libraries of polar compounds.

2.6.2 Oligomeric Bis-Acid Chloride

Hanson and coworkers recently reported a high-load, oligomeric, *bis*-acid chloride (OBAC) as a general nucleophile scavenger that was capable of removing alcohols and thiols in addition to amines.[51] The requisite monomer, *trans*-bicyclo [2.2.1] hept-5-ene-2,3-dicarbonyl dichloride, was conveniently prepared in a two-step sequence beginning with a Diels-Alder reaction between fumaric acid and cyclopentadiene followed by chlorination using oxaloyl chloride and catalytic DMF. Subsequent ROM polymerization with either the 1st or 2nd generation Grubbs catalysts[49] yields OBAC reagents of varying chain lengths (Scheme 2.37).

The OBAC scavenger was found to efficiently remove excess amines (1^{o}, 2^{o}), alcohols (1^{o}, 2^{o}, allylic, propargylic and benzylic) and thiols after a common benzoylation event yielding products with greater than 95% purity. The synthetic utility of the OBAC scavenger was assessed by comparing its efficiency against a commercially available polystyrene-based isocyanate (PS-NCO) resin. The "loading" of OBAC scavengers, is higher than the corresponding isocyanate polystyrene resin (9.1 mmol/g vs. ~1.3 mmol/g), thus the amount of OBAC reagent required for each scavenging reaction was determined to be seven times lower than the amount of isocyanate resin for a given experimental procedure. *In a typical comparison experiment, 35 mg of OBAC versus 250 mg of the polystyrene-based isocyanate was found to be optimal for scavenging.* Furthermore, from the perspective of sequestration ability, both OBAC and PS-NCO performed similarly for scavenging amines and thiols, OBAC was deemed more efficient for scavenging alcohol.

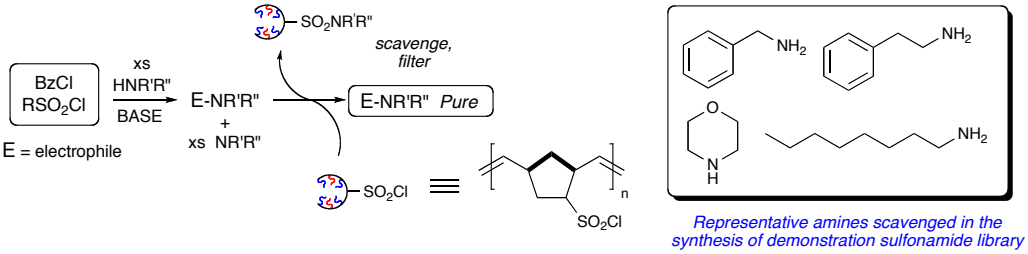
Scheme 2.37



2.6.3 Oligomeric Sulfonyl Chloride (OSC)

Hanson and coworkers also reported the development of a high load, soluble oligomeric sulfonyl chloride (OSC) for scavenging of amines (Scheme 28).[52] The synthesis of OSC was achieved by Diels-Alder reaction of vinylsulfonyl chloride and cyclopentadiene to generate monomer in 75-90% yield, followed by ROM polymerization with the 2nd-generation Grubbs catalyst[49] to produce a free flowing solid. This scavenger is soluble in CH_2Cl_2, THF, and DMF, and is insoluble in Et_2O, EtOAc, and MeOH. The scavenging ability of OSC was investigated in the benzoylation and tosylation of a variety of amines. Following the benzoylation/tosylation event, the oligomer was added as a solution to remove the excess amine (1^o, 2^o and benzylic), followed by precipitation of the scavenger to furnish the amides and sulfonamides in excellent yields and purities. Moreover, the solubility profile of this oligomer lends itself to facile dispensing via an automated liquid handling system, offering a distinct advantage over traditional solid-phase scavenging agents (Scheme 2.38).

Scheme 2.38

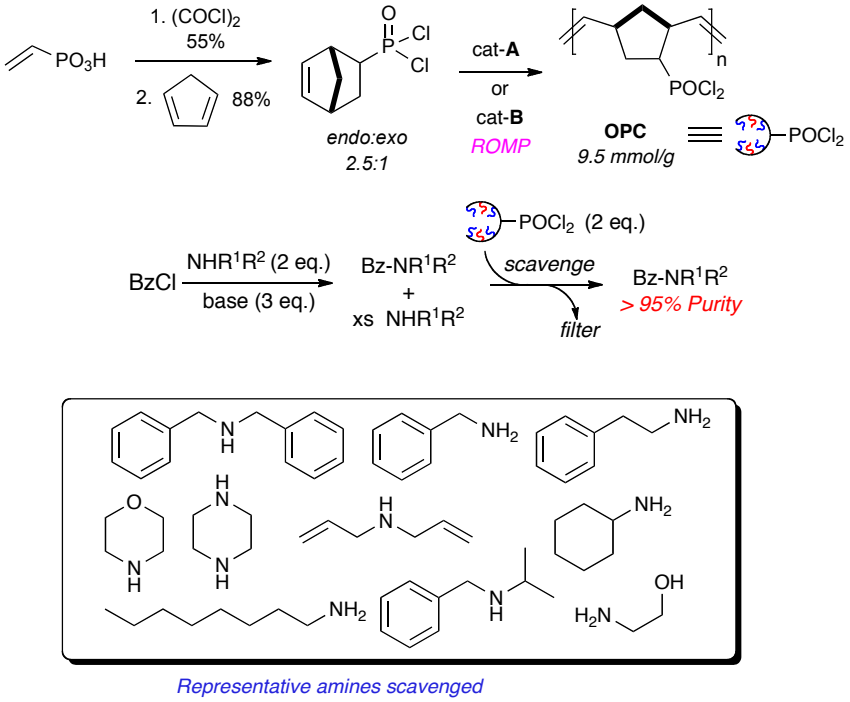


Representative amines scavenged in the synthesis of demonstration sulfonamide library

2.6.4 Oligomeric Phosphonyl Chloride

Hanson and coworkers have recently reported the development of a high-load, ROMP-derived phosphonyl chloride (OPC) scavenging agent for scavenging amines (Scheme 2.15).[53] This reagent can be readily generated via the ROM polymerization of bicyclo[2.2.1]hept-5-en-2-ylphosphonic dichloride, which is conveniently assembled from the Diels-Alder reaction of cyclopentadiene and vinylphosphonic dichloride. The OPC reagent was exploited in the rapid, efficient scavenging of primary and secondary amines that are present in excess following a common benzoylation event at room temperature (30-60 min) or under microwave conditions in shorter duration (<5 min). In addition, the scavenger was found to efficiently scavenge amines in the presence of alcohols with remarkable selectivity (Scheme 2.39).

Scheme 2.39



Representative amines scavenged

2.7 Conclusion

In this chapter we have discussed and summarized recent developments and applications of immobilized scavengers in organic synthesis. Building on earlier work using polystyrene resins, a new array of tagged- and immobilized reagents/scavengers has emerged. Their application in facilitated protocols aimed at drug discovery, as well as their use in natural product synthesis, points to a very bright future. Despite these successes, continued effort is needed for integrating and improving this technology into current and future platforms. In particular, progress in flow-through technology, coupled with recent advances made in the development of immobilized scavengers and reagents, allow for new and exciting possibilities for accelerating drug discovery.

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(52) Zhang, M.; Moore, J.D.; Flynn, D.L.; Hanson, P.R. *Org. Lett.* **2004**, *6*, 2657-2660.

(53) Herpel, R. H.; Vedantham, P.; Flynn, D. L.; Hanson, P. R. *Tetrahedron Lett.* **2006**, *47*, 6429-6432.

Chapter 3

Complementary Ambiphile Pairing (CAP) Strategies in Sultam Synthesis via in-situ Orthoquinone Methide Generation

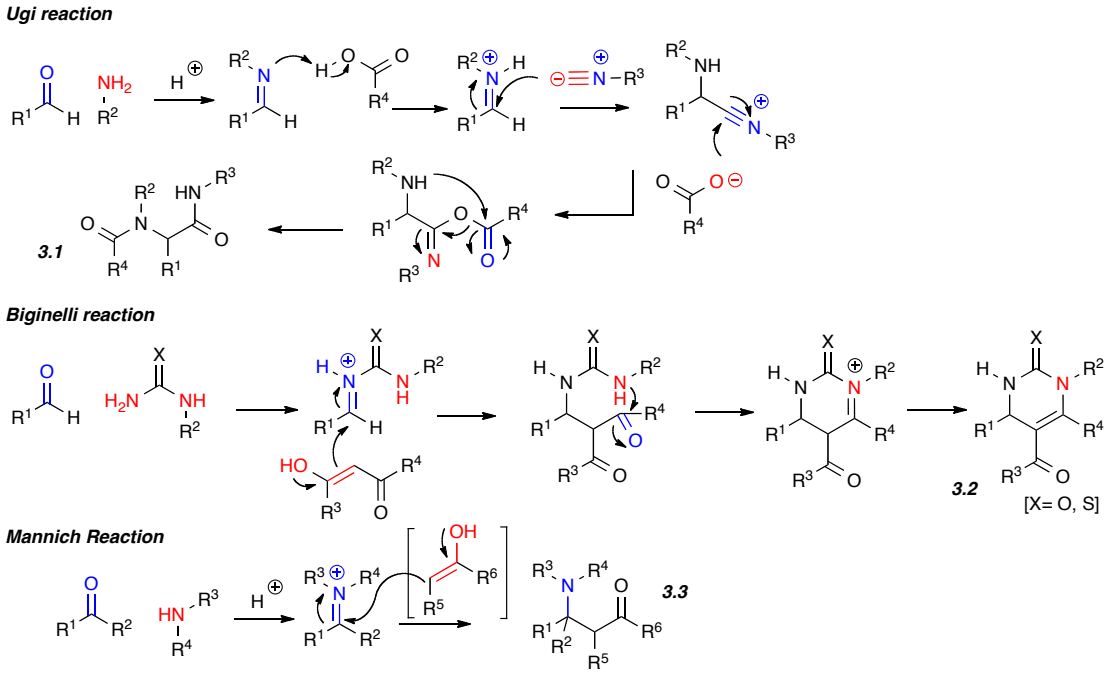
3.1. Introduction

The development of chemical methodologies allowing ready access to novel heterocyclic scaffolds in a minimal number of steps is a key facet of drug discovery.[1] The development of new synthetic strategies and reactions providing access to complex motifs in a step economical fashion has important implications from economical, environmental and synthetic perspectives.[2,3] Single pot, multi-component reaction (MCR) strategies[4] in particular have gained high value in this regard.[5]

The Ugi reaction, Passerini reaction, Biginelli reaction and Mannich reactions assume much prominence among multi-component reaction strategies due to their ability to generate pharmaceutically important motifs as well as an array of natural products[3,6,7,8,9,10] The Ugi reaction, which ranks prominently among MCR's, involves a series of sequential condensation reactions between an amine, aldehyde, isocyanide and a carboxylic acid to afford a peptide moiety (Scheme 3.1, reaction 1).[6] The Biginelli reaction entails a series of condensation reactions in sequential fashion between aldehydes, ureas and activated methylene compounds providing dihydropyrimidines (Scheme 3.1, reaction 2).[8] The Mannich reaction follows a similar pattern with the addition of a resonance stabilized carbon nucleophiles to imines producing β-amino carbonyl compounds (Scheme 3.1, reaction 3).[9] The Passerini reaction involves the reaction of an isocyanide with a carboxylic acid and an aldehyde/ketone to produce α-acyloxycarboxamide moieties. A recurring theme in

all of these reaction sequences is the involvement of singular nucleophile-electrophile interactions in sequential fashion to produce the desired target.

Scheme 3.1



Close analysis of contemporary non-transition metal catalyzed MCR strategies indicates that many of these strategies are variations of the aforementioned reaction sequences. Overall, the great majority of MCR sequences involve the interaction of reactive partners in singular nucleophile-electrophile interactions. Cyclic products are subsequently formed by the merging of intermediates in domino, cascade or tandem pathways.[11]

An alternative strategy to the aforementioned pathways is the interaction of ambiphilic synthons in bond forming events. Synthons containing both electrophilic

and nucleophilic sites may be described as ambiphilic synthons (Ambi: latin to mean "on both sides"; philic: "having an affinity for").[12,13,14]

The utilization of ambiphilic synthons for developing new reaction pathways represents an attractive option as it provides synthetic routes that are step economical. Testament to the synthetic potential of such systems are the isocyanide-MCR's including the Ugi and Passerini reactions along with their many variants.[1,13] The potential of ambiphilic synthons lie in its ability to undergo two discrete bond forming events thus serving essentially as a linchpin in the construction of linear acyclic systems as well as cyclic systems. However, in spite of its potential as well as the availability of a number of these synthons, this area remains highly under-developed and under-utilized in organic synthesis (Figure 3.1).

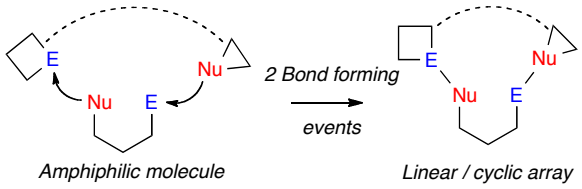
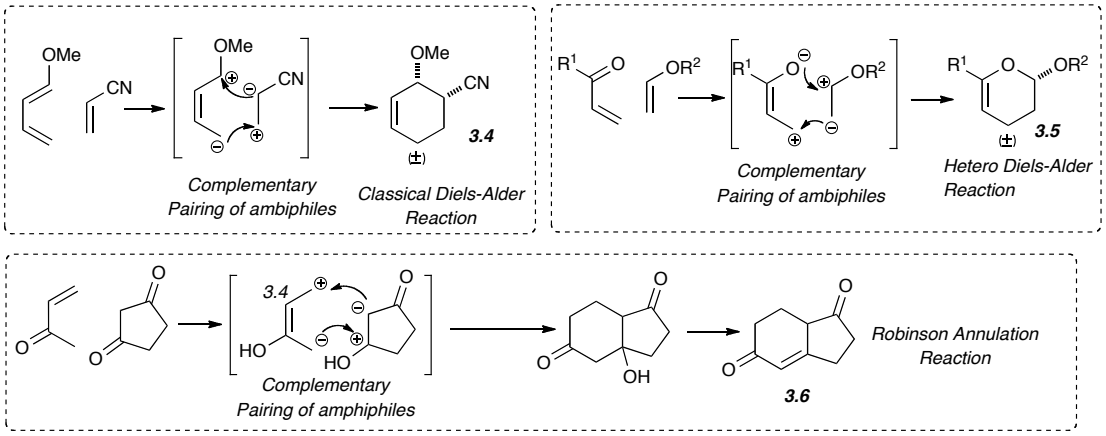


Figure 3.1

The merging of two ambiphilic synthons in a manner analogous to the lock and key principle of molecular recognition in chemical biology presents interesting opportunities to access new heterocyclic systems in a facile fashion.[15] Such a process allows merging synthons in a [m+n] manner with the simultaneous formation of a pair of bonds affording a synthetic sequence with high step economy (Figure 3.2).[16] Cycloaddition reactions[17] including Diels-Alder reactions[18] as well as dipolar cycloadditions[19] and the Robinson annulation[20] reaction are prime examples of two

ambiphilic synthons merging in complementary fashion to afford desirable molecules with high atom and step economy (Scheme 3.2).[2,16]

Scheme 3.2



Interest in the development of chemical methodologies for the production of diverse sultam libraries has led to the exploration of novel, complimentary ambiphile pairing (CAP) pathways as part of a general strategy for the production of benzofused sultams (Figure 3.2).

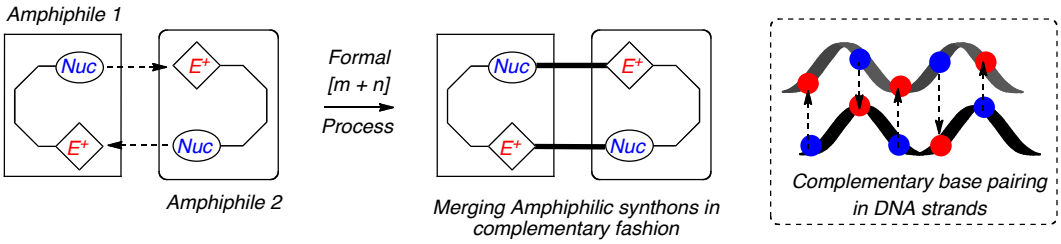
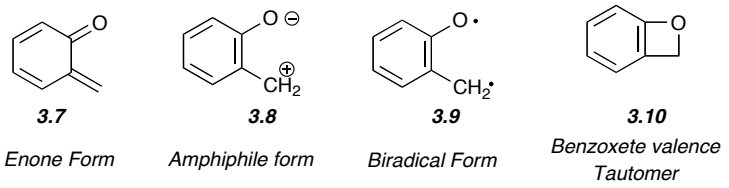


Figure 3.2.

3.2. Background Significance

Quinone methides are reactive intermediates that have been known for more than half a century and represent a versatile class of reactive intermediates.[21] In particular, ortho quinone methides (*o*-QM's) are highly versatile intermediates and their widespread participation in a number of biological processes is testament to the potential of *o*-QM's (vide infra). These intermediates are highly polar in character, having a number of plausible representations, and hence imbue *o*-QM with a great deal of reactivity. The enone form, **3.7** is particularly interesting from a chemical reactivity viewpoint due to the ability for *o*-QM's to serve as Michael acceptors or dienes in cycloaddition reactions (Figure 3.3).[21]

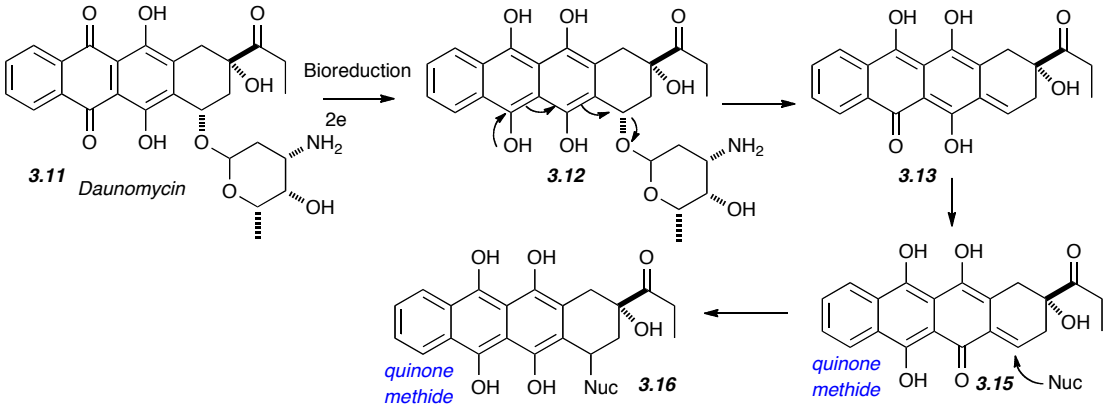


3.7 *Enone Form* ***3.8*** *Amphiphile form* ***3.9*** *Biradical Form* ***3.10*** *Benzoxete valence Tautomer*

Figure 3.3

o-QM's have been proposed as the reactive species responsible for the occurrence of biological activity of a number of natural products.[22] In particular the exhibition of potent anti-tumor activity of DNA targeting antibiotics such as mitomycin C,[23] saframycin,[24] dynamicin,[25] and daunomicin[26] are attributed to their ability to form *o*-QM's *in situ*. It is proposed that these quinone containing natural products undergo bio-reduction followed by generation of *o*-QM intermediates thus setting the stage for alkylation of DNA via aza-Michael pathways (Scheme 3.3).[21,22]

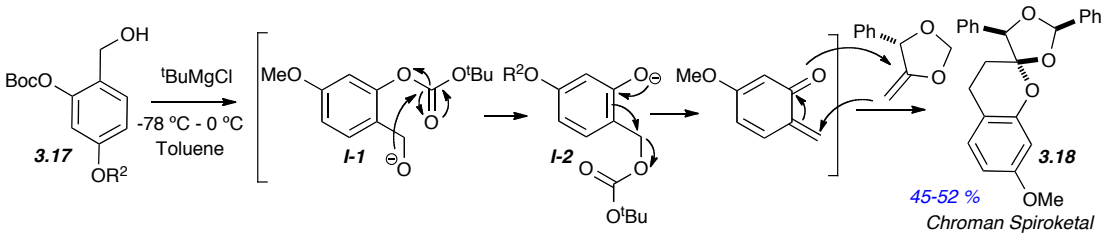
Scheme 3.3



In spite of the reaction potential of *o*-QM's, their synthetic potential remains largely untapped and has largely been limited to use as dienes in hetero Diels-Alder reactions.[27] A number of natural products as well as biologically active heterocycles have been accessed utilizing *in situ* generated *o*-QM's in hetero Diels-Alder reactions for the synthesis of benzopyran motifs.[20]

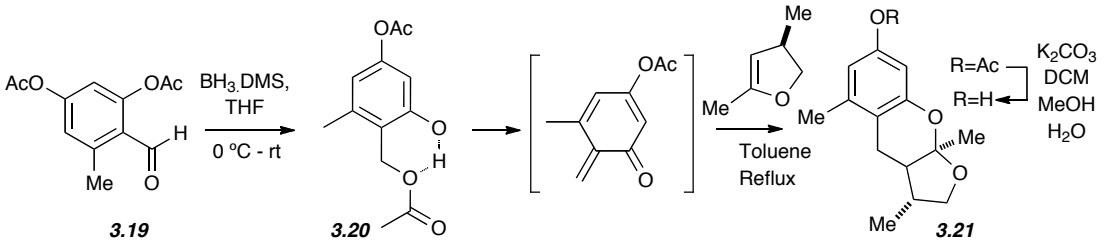
Pettus and coworkers have been major contributors in the use of *o*-QM's in the synthesis of natural products and small molecules.[28] Pettus and coworkers have recently described the diastereoselective synthesis of a series of chroman spiroketals via [4+2] hetero Diels-Alder reaction of *in-situ* generated *o*-QM's with an array of cyclic exomethylene enol ethers.[27] OBoc benzyl alcohol **3.17** was deprotonated at low temperatures allowing for transfer of the Boc group to the newly formed alkoxide, thus forming the phenoxide **I-2** which in turn allows for the β-elimination of the carbonate to generate the *o*-QM at low temperatures (Scheme 3.4).[29]

Scheme 3. 4



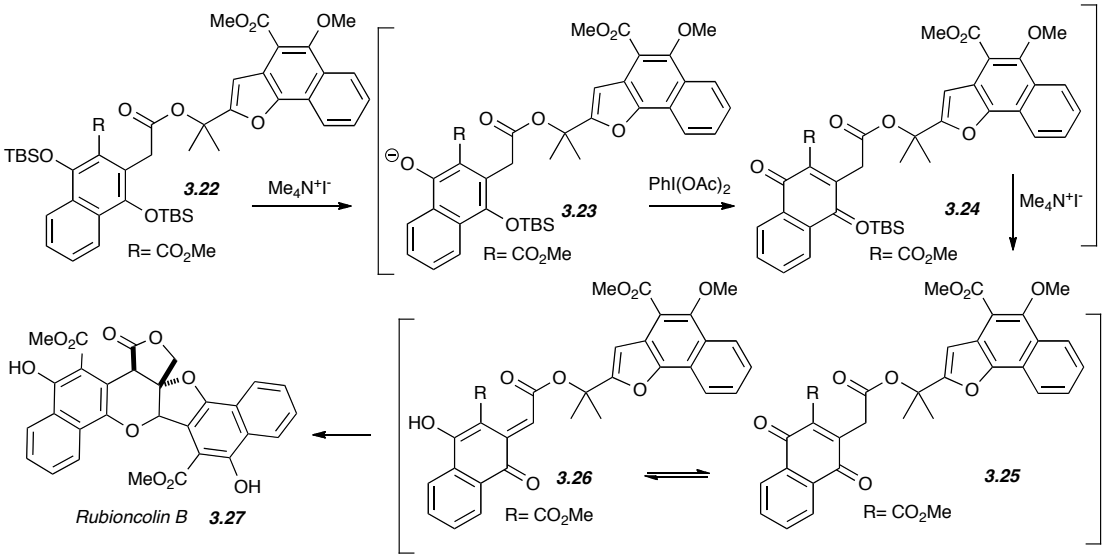
Baldwin and Coworkers have described the synthesis of *rac*-Alboatrin, a phytotoxic natural product via an *o*-QM pathway. Thus, treatment of the bis-acetoxy benzaldehyde **3.19** with BH_3-DMS affords the trans-esterified product, **3.20.** Subjection of this product to refluxing conditions in toluene allowed for its thermal decomposition thus generating the requisite *o*-QM which underwent a [4+2] hetero Diels-Alder reaction to afford *rac*-Alboatrin in 90% yield (Scheme 3.5).[27,30]

Scheme 3. 5



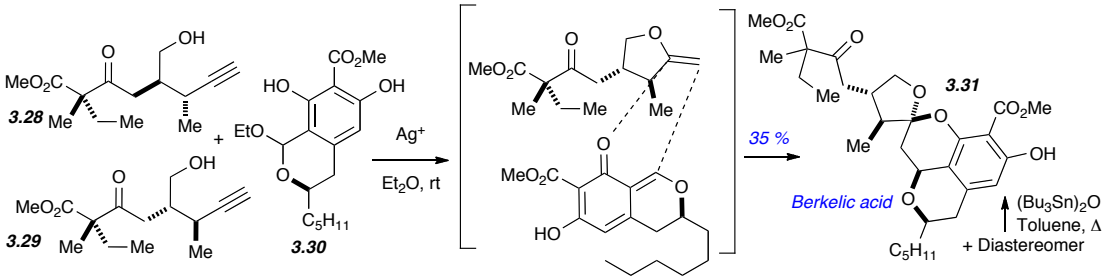
Trauner and coworkers have described the utilization of *o*-QM for the total synthesis of Rubioncolin B. In an approach emulating nature,[31] the authors generate the desired *o*-QM via tautomerization of its *para*-quinone methide counter part and the *o*-QM is allowed to undergo an intramolecular [4+2] hetero Diels-Alder reaction to afford the desired product Rubioncolin B (Scheme 3.6).[32]

Scheme 3.6



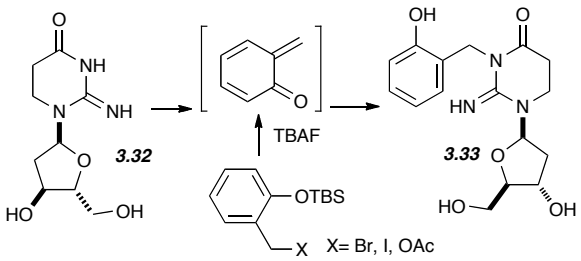
More recently, Brebander and coworkers have reported the total synthesis of Berkelic acid, a natural product exhibiting inhibitory activity against a number of targets including human ovarian cancer cell line OVCAR-3, matrix metalloproteinase MMP-3 and cysteine protease caspase-1.[33] The pivotal step in this work involved a intermolecular [4+2] hetero Diels-Alder reaction between an in situ generated *o*-QM and a cyclic exomethylene enol ether to generate the spirocyclic natural product.[27] Treatment of the ethoxyisochromanol moiety with $AgSbF_6$ resulted in a cascade reaction to generate the desired *o*-QM under mildly acidic conditions. The above Lewis acid also induced a cycloisomerization of the alkynol fragment to generate the desired cyclic enol ether in the same pot, and subsequent merging of these two fragments via a [4+2] pathway completed the effort all in a single pot (Scheme 3.7).

Scheme 3.7



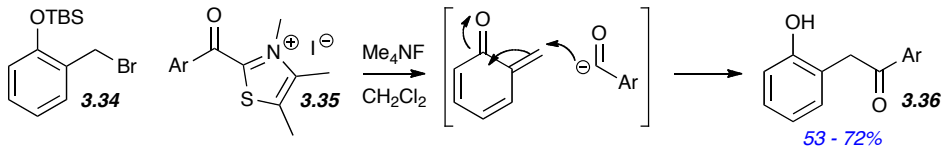
The Michael accepting ability of *o*-QM's has been have been investigated by a number of groups with the aim of exploring the biological activity of quinone containing molecules and these reactive intermediates have been found to undergo Michael additions with an array of nitrogen, oxygen, sulfur and carbon nucleophiles. Notably, Rokita and coworkers have extensively investigated the aza-Michael additions of nucleoside bases to *in-situ* generated *o*-QM's in an effort to understand the biological acitivity of anthacycline antibiotics.[21a] Thus, the Rokita group has developed the *o*-silyloxy benzyl halides and acetates for *in-situ* generation of *o*-QM which in the precence of nucleosides have been found to undergo reversible alkyaltion via aza-Michael pathways (Scheme 3.8).[21a]

Scheme 3.8



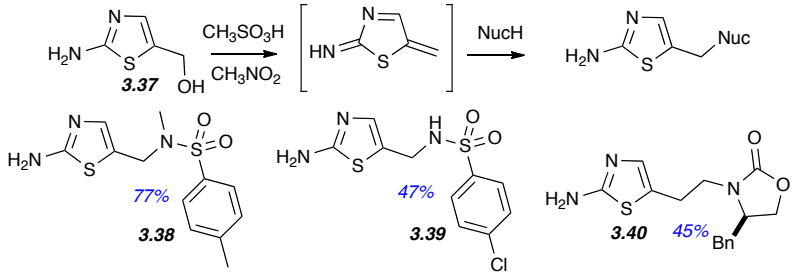
In contrast, the utilization of Michael addition pathways in synthetic applications seems largely relegated to the synthesis of acyclic precursors. Recently elegant use of acyl-anion Michael additions into *o*-QM's has been reported by Scheidt and coworkers for the generation of α-aryl ketones. This involves the *in-situ* generation of acyl anions along side the *in-situ* generation of *o*-QM under a fluoride source. Thus treatment of silyl protected thiazolium carbinols with *o*-silyloxy benzyl bromide in the presence of TMAF affords an array of α-aryl ketones in good yields (Scheme 3.9).[34]

Scheme 3.9



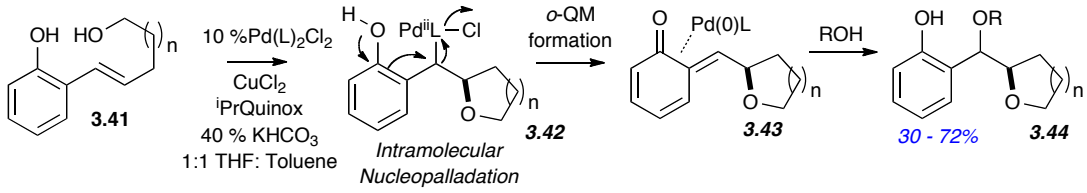
More recently Saulnier and coworkers have reported the nucleophilic capture of quinone methide imine type intermediates. This work involves the acid-mediated addition of an array of nucleophiles including alcohols, amines and sulfonamides to amino thiazole carbinol **3.37** generating a variety of substituted amino thiazoles. It is proposed that treatment of the amino thiazole carbinol with methane sulfonic acid allows for the formation of a quininemethide imine type intermediate followed by subsequent nucleophilic addition (Scheme 3.10).[35]

Scheme 3.10



Sigman and coworkers have demonstrated the Pd-catalyzed oxa-Michael addition of alcohols to *in-situ* generated *o*-QM's formed from 2-hydroxy styryl moieties. This unique approach entails the intramolecular nucleopalladation of styryl-tethered alcohols to produce cyclic ethers, followed by *o*-QM formation and subsequent oxa-Michael addition of alcohols with release of Pd(0) to afford a variety of alkoxy ethers (Scheme 3.11).[36]

Scheme 3.11



3.3. Development of CAP strategies for Sultam Synthesis: A Formal [4+4] Cyclization between α-Fluorobenzenesulfonamides and *in situ* Generated Orthoquinone Methide.

To the best of our knowledge the ability of *o*-QM's to undergo facile aza-Michael addition has not been utilized for the synthesis of heterocycles. However, the facile nature of Michael pathways coupled with the reactive, ambiphilic character of *o*-QM's lends tremendous potential for utilization of these reactive intermediates for the facile generation of heterocyclic systems and warrants further study.

Sultams (cyclic sulfonamides) are a class of non-natural heterocycles that have gained prominence in recent years due to their activity against a wide spectrum of biological targets.[37,38] In particular, benzofused sultams have been found to display myriad biological activity against an array of different targets and will be discussed in further detail in the chapter 4.[39] The design of sulfonamide linchpins and compatible reaction pathways for the construction of sultams presents opportunities as well as challenges in this area. In particular, methods for the generation of medium sized sultams have been limited to ring-closing metathesis approaches or Pd-catalyzed Heck approaches. [40,41] Moreover, the conditions required in these cases are often harsh and the methods used are neither short nor straightforward.[40]

Sulfonamides (acyclic precursor of sultams), are highly versatile synthons with great synthetic potential.[42,43] This synthetic versatility stems from the highly tunable nature of sulfonamide N-H pKa and the nucleophilic/electrophilic character

of carbon atoms at the α- and β-positions of the sulfonamide, ultimately lending disparate reactivity profiles to these synthons.[42] This allows the use of sulfonamide synthons as linchpins for the construction of diverse sultam skeletons. In this regard we have identified synthetically useful sulfonamide linchpins in the following four groups: (i) aryl sulfonamides, (ii) vinyl sulfonamides, (iii) alkynyl sulfonamides and (iv) alkyl sulfonamides. Furthermore, the nucleophilic/electrophilic character of the aforementioned sulfonamide linchpins allow for the identification of these systems as ambiphilic sulfonamides (aryl sulfonamides, **3.45** and vinyl / alkynyl sulfonamides, **3.46**) or bis nucleophilic sulfonamides (alkyl sulfonamides, **3.47**) (Figure 3.4).

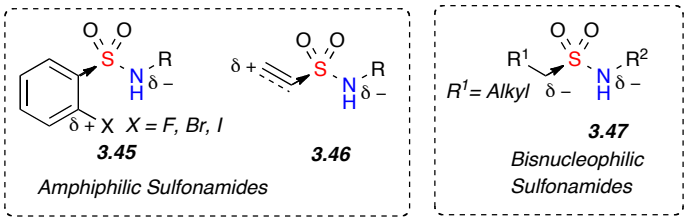
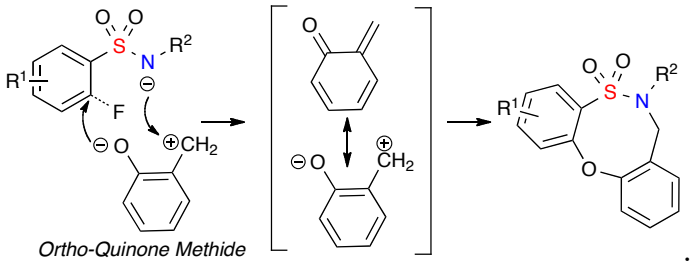


Figure 3.4

As an ambiphilic synthon, α-fluoro benzene sulfonamides have synthetic potential that is largely unrealized. The highly electron withdrawing nature of the sulfone functionalty, in conjunction with the α-fluoro substituent, impart enhanced electrophilicity at the β-carbon as well as attenuated acidity of the sulfonamide N-H. This increased acidity of the sulfonamide N-H enables for facile deprotonation under mild conditions to afford an ambiphilic synthon (Scheme 3.12). The ability of α-fluoro benzene-sulfonamides to undergo facile aza-Michael additions reactions, as well as nucleophilic aromatic substitution (S_NAr) reactions at the β-carbon, allow for

their potential pairing with *o*-QM's in CAP strategies for production of benzofused sultams.[43,44] This pairing entails an aza-Michael addition at the exo methylene *o*-QM carbon, and subsequent interception of the nucleophilic phenoxy by α-fluoro benzenesulfonamides via an S_NAr reaction in a formal [4+4] cyclization process to produce medium sized benzofused sultams in a single step (Scheme 3.12).

Scheme 3.12

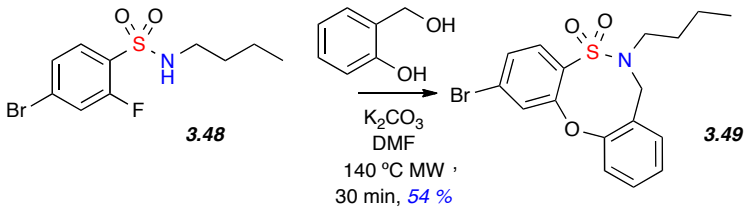


3.4. Results and Discussion

Investigations commenced with the production of an array of 2º α-fluoro benzene sulfonamides under modified Schotten-Bauman conditions.[45] It is a well established fact that *o*-QM's can be formed in situ from 2-hydroxy benzyl alcohol derivatives under basic conditions.[21] Furthermore, basic conditions are required to alkylate sulfonamides. Accordingly, a mixture of 4-bromo-*N*-butyl-2-fluorobenzenesulfonamide **3.48** was mixed with 2-hydroxy benzyl alcohol in the presence of anhydrous K_2CO_3 (3.0 equiv.) in DMF and was subjected to microwave irradiation (*m*W) at 140 ºC for 30 minutes. The sulfonamide starting material was consumed completely to afford a highly UV active compound. Complete characterization of the product utilizing 1-D as well as 2-D NMR (COSY, HSQC,

DEPT) spectroscopy in conjunction with IR spectrosciopy as well as HRMS revealed a novel tricyclic sultam **3.49** containing an 8-member oxazocine ring system (Scheme 3.13). To the best of our knowledge, the ring system produced has not been reported in the literature. Furthermore, the method reported represents the first instance of the use of an *o*-QM in a formal [4+4] cycloaddition process in a single pot. It is also pertinent to note that this also represents the first reported instance of the utilization of *m*W irradiation in conjuction with *in-situ* generated *o*-QM's in heterocycle formation.

Scheme 3.13.



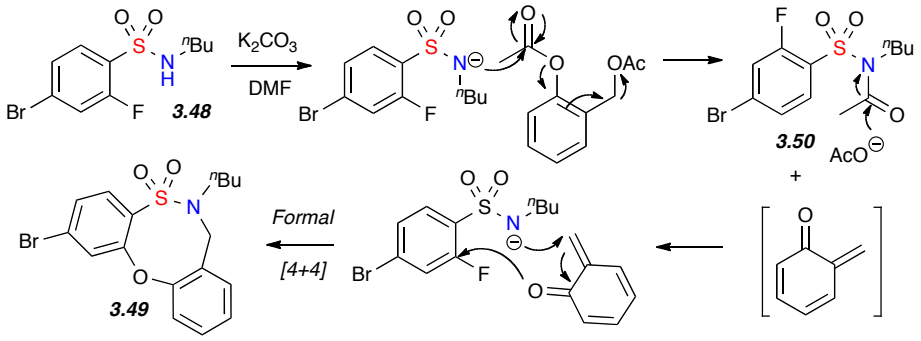
However, the overall yield of the reaction was at best modest, possibly due to inefficient generation of the *o*-QM intermediate. An attempt was also made to repeat this experiment under conventional heating conditions as we suspected that subjection of *o*-QM precursor to *m*W conditions might have a deleterious effect on the highly reactive *o*-QM. Accordingly, heating a mixture of the 4-bromo-N-butyl-2-fluorobenzenesulfonamide **3.48** at 110 °C in DMF for 12 hours under reflux afforded the desired product albeit in incomplete conversion and low product yields. Further studies revealed that intermolecular S_NAr additions of nucleophiles to α-fluorobenzene sulfonamides require *m*W heating to afford high yields and complete

conversions (See Chapter 4 for more details). Moreover, the lengthy heating time allows for the dimerization, trimerization and polymerization of the *o*-QM. Taken collectively, we concluded that the aforementioned factors led to the observed results for our reaction protocol under conventional heating. It was surmised that since *m*W heating allows for short reaction times along with the attainment of desired temperatures in quick fashion prompted the further investigation of *m*W-assisted reaction protocols. Furthermore, given the harshness of the initial set of conditions and the notoriety of *o*-QM to undergo rapid dimerization, trimerization and polymerization under these high temperature conditions prompted the investigation of alternate methods for generating the key *o*-QM intermediate.

Investigations focused on alternate methods of *o*-QM generation. We surmised that the introduction of the leaving group on the *o*-QM precursor would allow for the efficient generation of the desired intermediate. Accordingly, attempts were made to prepare 2-hydroxybenzyl acetate and subjecting 2-hydroxybenzyl alcohol to standard acylation conditions afforded the bis acylated product. Thus, stirring the test substrate in the presence of 2-acetoxybenzyl acetate (2.0 equiv.) under *m*W heating at 140 ºC furnished the desired tricyclic product in increased yields. This result was completely unexpected, as it has no precedence in the literature. However, given the propensity for sulfonamides to undergo acylation (see chapter 5) the following explanation is given.

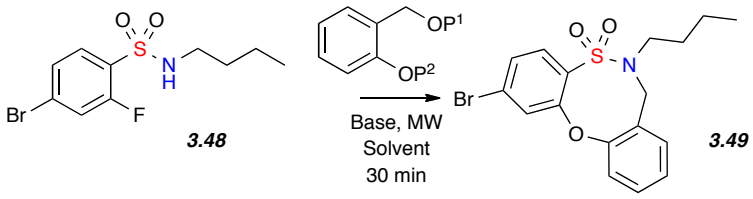
The sulfonamide undergoes an initial acylation to generate the phenoxide anion, which undergoes an electron cascade to produce the *o*-QM intermediate upon release of the acetoxy leaving group. This acetoxy group thereafter undergoes nucleophilic attack on the acyl sulfonamide **3.50** due to the enhanced electrophilicity at the acyl C to afford the desired sulfonylamide. The two intermediates (the sulfonylamide and the *o*-QM) thereafter are poised to undergo the formal [4+4] reaction to afford the desired product (Scheme 3.14).

Scheme 3.14. Proposed mechanism for *o*-acetoxy benzyl acetate mediated reaction.



Interestingly, use of the *o*-tosyloxybenzyl tosylate as the *o*-QM precursor employing the conditions established above did not afford the desired product while the *o*-hydroxy benzyl acetate provided the desired product in only slightly increased yields. Attention was then turned to the conditions reported by Rokita and co-workers. Accordingly, *m*W irradiation of sulfonamide in the presence of TBAF (3.0 equiv.) and *o*-silyloxy benzyl acetate (2.0 equiv.) in THF at 100 ºC for 30 minutes furnished the desired product in 90 % yield (Table 3.1).

Table 3.1

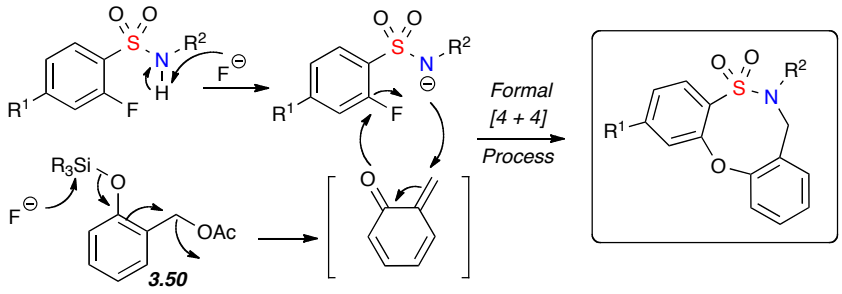


Entry	P^1	P^2	Yield[a] (%)
1	H	H	64
2	OTs	OTs	0
3	OAc	OAc	74
4	OAc	H	76
5	OAc	OTBS	90

[a] Isolated yields after column chromatography

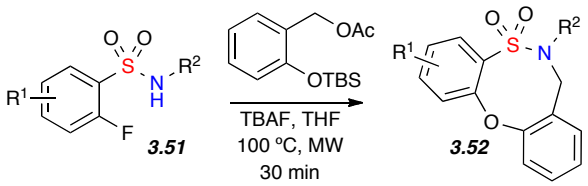
In this latter result, fluoride serves to desilylate the silyl protected phenol functionality thus generating the phenoxy anion which cascades to produce the pivotal *o*-QM intermediate. It also serves as the base to produce the sulfonylamide intermediate required for the desired reaction to take place (Scheme 3.15).

Scheme 3.15



With optimized reaction conditions in hand the substrate scope of our formal [4+4] CAP reaction was investigated.

Table 3.2. Substrate scope of o-QM mediated [4+4] reaction



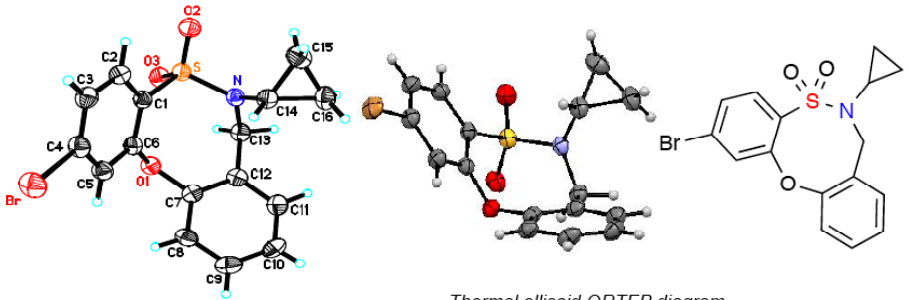
Entry	R^1	R^2	Pdt	Yield[a] (%)
1	H	2-OMe Bn	3.52a	71
2	H	2,3-Cl CH_2Ph	3.52b	73
3	4-Br	^{n}Bu	3.52c	90
4	4-Br	^{i}Bu	3.52d	91
5	4-Br	PMB	3.52e	82
6	4-Br	cyclopropyl	3.52f	81
7	4-Br	propargyl	3.52g	94
8	4-Br	$(CH_3)CHPh$	3.52h	72
9	5-Cl	Allyl	3.52i	94
10	5-Cl	PMB	3.52j	71
11	5-Cl	3-F Bn	3.52k	93
12	5-Cl	2-OMe Bn	3.52-l	87
13	5-Cl	2,3-Cl CH_2Ph	3.52m	83

[a] isolated yields after column chromatography

A number of sulfonamides were subjected to the optimized conditions mentioned above and proceeded smoothly to afford the desired sultams in excellent yields (Table 2).

The reaction protocol was found to tolerate a variety of substituents on the nitrogen atom including alkyl, propargyl and benzyl functionalities. Halide substitution on aromatic rings including bromide as well as chloride was important, as this would allow for functionalization of these scaffolds for library production via transition metal catalyzed coupling reactions. Pleasingly, the reaction protocol was found to tolerate halides.

The uniqueness of these heterocyclic systems as well the observance of a few ^{1}H NMR δ anomalies (vide infra) prompted the examination of selected systems via X-ray crystallography. This not only confirmed the structure of these unique heterocyles, but offered an explanation for the observed ^{1}H NMR chemical shifts (Figure 3.5).



Thermal ellisoid ORTEP diagram At 50 % probability of 2f generated using SHELXTL

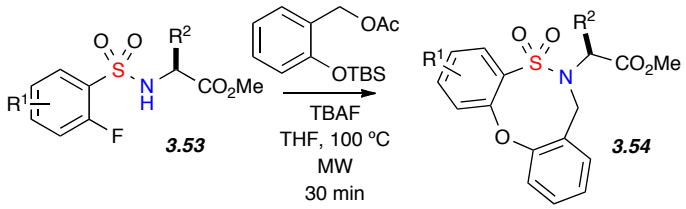
Thermal ellisoid ORTEP diagram At 50 % probability of 2f generated using Mercury 2.3

Figure 3.5: X-ray structure of dibenzo[*b*,*g*][1,4,5]oxathiazocine-5,5-dioxide **3.52f**.

The OTREP structure of **3.52f** was generated utilizing both SHELXTL as well as Mercury 3.2.[46] These revealed a rigid cup shaped system. The H atoms at C-13 exhibited a remarkable 1.2 ppm δ difference (J = 16 Hz) in the ^{1}H NMR spectrum. This is ascribed to the conformational rigidity of the system allowing for the placement of the geminal H atoms at C-14 in different magnetic environments. The X-ray crystal structures clearly shows the H atom at C-14 protruding in between the two flanking aromatic ring systems and hence is subject to severe diamagnetic deshielding and hence provides an explanation for the observed chemical shift of the H atom at C-14 at 1.0 ppm.

The incorporation of amino acids into scaffolds is an important aspect of scaffold design for library synthesis as it allows access to stereochemical and peripheral diversity. Therefore, the application of the *o*-QM mediated [4+4] CAP strategy employing amino ester-derived α-fluorobenzenesulfonamides was also investigated (Scheme 3.16).

Scheme 3.16: Amino acid derived substrates in [4+4] reaction



Treatment of an array of amino acid-ester derived substrates under above conditions gratifyingly afforded the desired product in excellent yields (Table 3.3). This result was important for enhancing the scope of the method and was a crucial

result for library production efforts as it allows for further elaboration of the scaffolds in library efforts as well as diversity-oriented synthesis efforts.[47]

Table 3.3

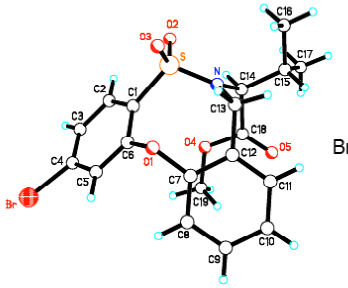
Entry	R^1	R^2	Pdt	Yield[a] (%)
1	4-Br	^{i}Pr	3.54a	93
2	4-Br	^{i}Bu	3.54b	77
3	4-Br	^{s}Bu	3.54c	84
4	5-Cl	^{i}Pr	3.54d	76
5	5-Cl	^{i}Bu	3.54e	71
6	H	^{i}Pr	3.54f	34

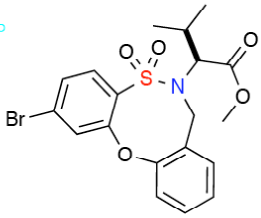
[a] Isolated yield after column chromatography

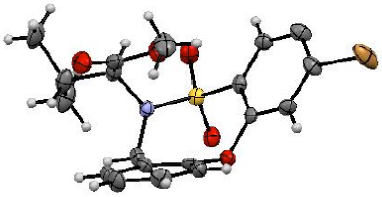
Again, lack of halide substitution in the aromatic ring attached to the SO_2 functionality afforded poor yields and is consistent with previous observations. We believe that the presence of halides on the aromatic ring allows for stabilization of the Meisenhemer complex formed in the S_NAr step via inductive effects due to the electronegativity of the halides.[48] On the other hand, absence of these stabilizing groups would retard intramolecular S_NAr addition allowing for the regeneration of the reactive *o*-QM. This allows its subsequent dimerization to predominate, thus reducing the yields of these reactions.

NMR spectra of these compounds offered some important information. The methyl group of the OMe functionality appeared at 2.43 ppm in comparison to 3.5

ppm for the sulfonamide precursor. The X-ray structure benzofused sultam **3.54a** indicated the remarkable placement of the carbomethoxy functionality inside the cuplike structure of the rigid tricyclic ring system, allowing for the methyl group to be subject to severe diamagnetic shielding (Figure 3.6).







Thermal Elipsoid ORTEP Diagram at 50% probability - SHELXTL Plot

Thermal Elipsoid ORTEP Diagram at 50% probability - Mercury 2.0 Plot

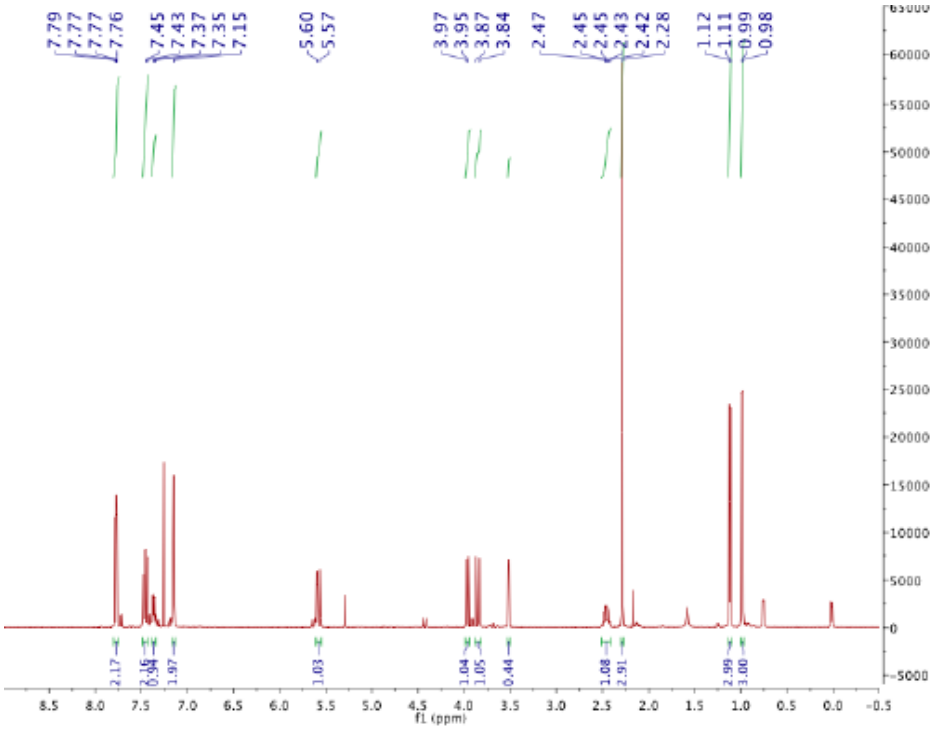


Figure 3.6

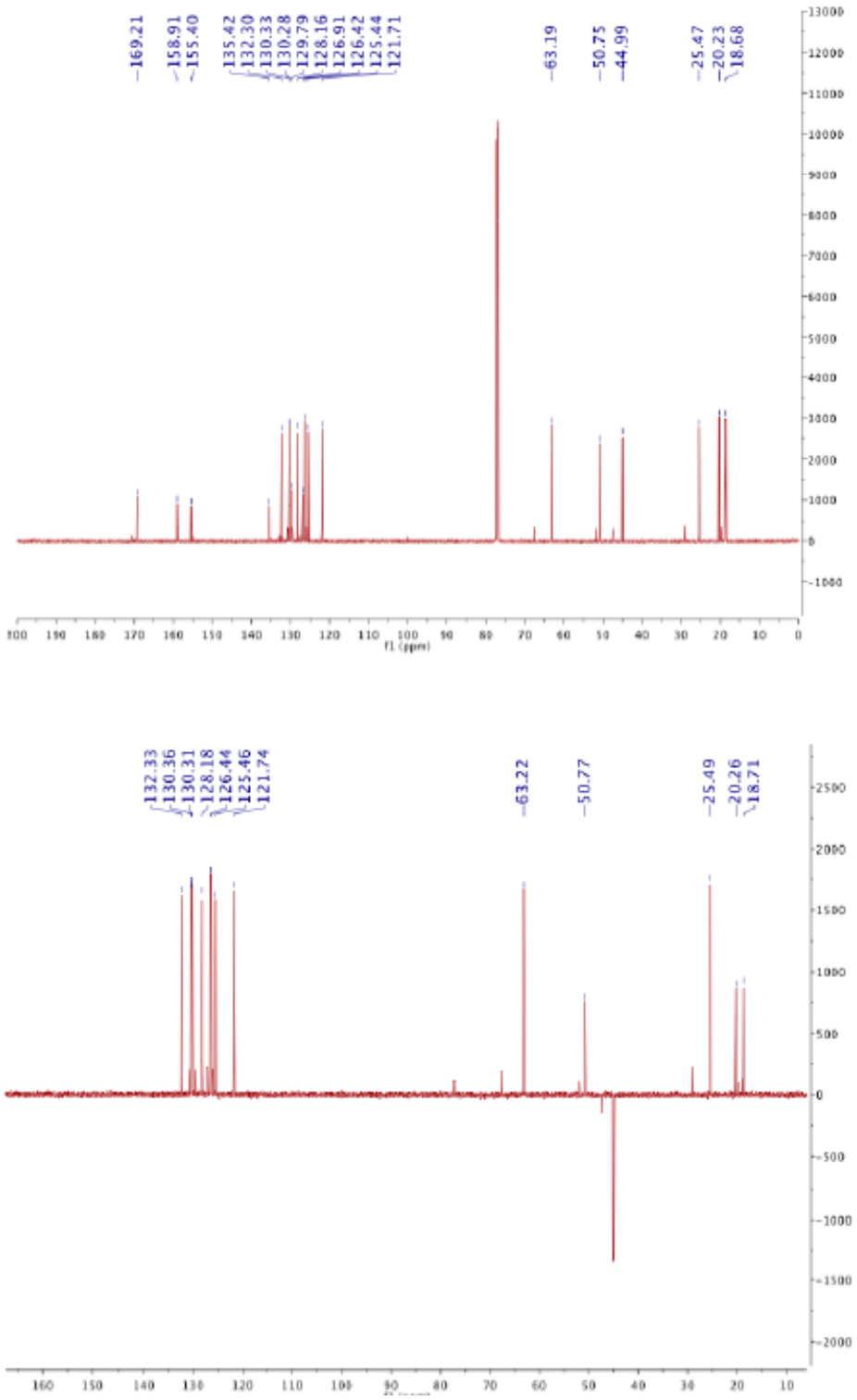
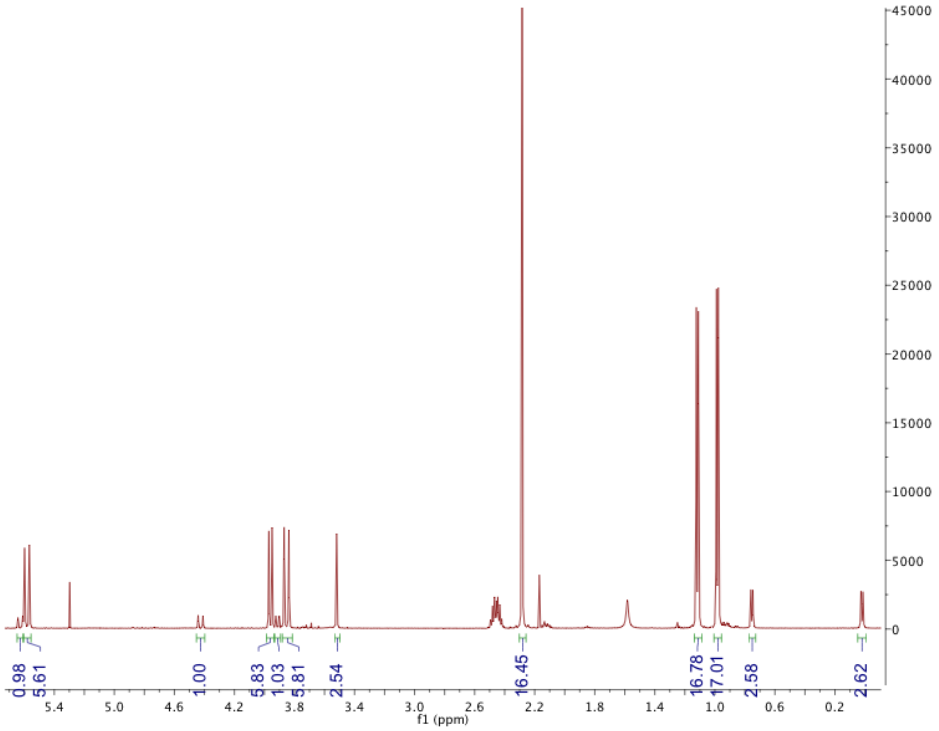

169.21
158.91
155.40
135.42
132.30
130.33
130.28
129.79
128.16
126.91
126.42
125.44
121.71
63.19
50.75
44.99
25.47
20.23
18.68
f1 (ppm)
132.33
130.36
130.31
128.18
126.44
125.46
121.74
63.22
50.77
25.49
20.26
18.71

Figure 3.7

Table 3.4: Selected ^{1}H NMR (500 MHz, $CDCl_3$) comparison data



Entry	Chemical Shift (δ)	Multiplicity	J (Hz)	Rel. Intensity
1	5.63	d	16.0	1.0
2	**5.58**	**d**	**15.9**	**5.82**
3	4.43	d	16.0	1.0
4	**3.85**	**d**	**15.9**	**5.96**
5	**3.96**	**d**	**10.9**	**5.95**
6	3.91	d	11.3	1.0
7	3.52	s	-	2.6
8	**2.28**	**s**	**-**	**17.2**
9	**1.1, 0.98**	**d, d**	**6.3, 6.4**	**16.8, 17.0**
10	0.75, 0.02	d, d	6.5, 6.6	2.6, 2.6

The NMR spectra upon close examination also revealed the presence of a possible minor product. The ^{1}H, ^{13}C and DEPT all showed the existence of a set of peaks that was a complete copy of the major product albeit with a change in chemical shift values, but matching the expected structure of the product (Figure 3.7/3.8) In particular, the OMe methyl group (C-19) of the minor product appears at 3.96 ppm while C-6 and C-7 of the valine side chain appear upfield at 0.75 ppm and 0.02 ppm respectively (Table 3.4). With this information in hand, we are tentatively ascribing this minor product as a rotamer. Since the valine side chain seems to be subject to severe shielding, it follows that this particular product has the valine side chain placed in the cup of the tricyclic sytem while placing the C-19 OMe group away from the aromatic rings. Overall, this leads us to assign the rotation of the N-C14 bond to afford the two rotamers with a ratio of approximately 6:1 – 7:1 in favor of the rotamer containing the OMe placed inside the aromatic cavity. All scaffolds containing a chiral center showed the formation of rotamers.

3.5. Summary and Future Outlook

In conclusion, a one-pot complementary ambiphile-pairing (CAP) strategy has been developed to produce dibenzo[*b*,*g*][1,4,5]oxathiazocine-5,5-dioxides in a formal [4+4] reaction via the *in-situ* generation of *o*-QM's under *m*W conditions. This report represents the first instance of the generation of dibenzooxazocine-1,1-dioxide scaffolds and the first reported method utilizing *in-situ* generated *o*-QM under *m*W conditions in a formal [4+4] process. This method is eminently suited for the production of combinatorial libraries as well as diversity-oriented synthesis approaches since the core scaffold can be achieved in two steps utilizing 3 components that are derived from commercially available, relatively inexpensive SM. From a synthetic methodology stand point, the next improvement of this process should focused on the expansion of the *o*-QM component with the goal of incorporating functional groups that are interesting from a medicinal chemistry perspective. Additionally, the extension of this methodology toward an enantioselective variant would be desirable for utilization in DOS-approaches.

Furthermore, the novel nature of the dibenzothiaxazocine-4,4-dioxide scaffold means that the biological activity of these scaffolds have not been investigated. At the time of writing 17 compounds reported here has been sent to the NIH Molecular Libraries Screening Network for screening for biological activity.

This work is the first reported instance of a complimentary ambiphile pairing (CAP) approach to the production of scaffolds and we believe that it is an approach

that would be of great value to the synthetic community who are in pursuit of producing drug-like compounds in a facile step economical fashion.

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Chapter 4

Development of Orthogonal Reaction Pairing Strategies toward the Synthesis of Benzofused Sultams.

4.1. Introduction

Rapid advances in biology have spurred growth in high throughput screening (HTS) efforts for drug discovery. Consequently, growing demands for quick access to small molecules with novel architectures have provided challenging opportunities for synthetic chemists in drug discovery. Diversity-oriented synthesis (DOS) has emerged to address these challenges as an enabling platform for the production of small molecules for accessing broader regions of chemical and biological space.[1,2,3] Among several key features of DOS, forward synthetic analysis and functional group pairing have surfaced as significant tools.[3,4] The Build-Couple-Pair (BCP) concept reported by Schreiber and coworkers represents a powerful planning strategy within forward synthetic analysis for producing multiple scaffolds in the fewest possible steps while generating skeletal and stereochemical diversity.[5] At the heart of this chapter is a DOS strategy based on orthogonal reaction pairing pathways allowing for the facile production of benzofused sultam scaffolds utilizing the ability of α-fluorobenzenesulfonamides to undergo facile nucleophilic aromatic substitution (S_NAr) with an array of nucleophiles.

The development of new chemotypes and corresponding reaction pathways that afford diverse molecules in a facile manner is an important aspect of DOS.[5] In this regard, the design and synthesis of diverse chemotypes not found in nature is a primary component of this endeavor. Sulfonamides are found to exhibit a broad range of biological activity despite the fact that sulfonamides are rarely found in

natural products.[6,7] Consequently, a number of currently marketed drugs contain sulfonamides.[8] Additionally, sultams (cyclic sulfonamides) represent a class of non-natural molecules that have gained prominence in recent years due to the exhibition of a wide spectrum of biological activity.

4.1.1. Biological profile of Sultams

Sultams display a broad spectrum of biological activity and serve as core subunits in bioactive compounds possessing inhibitory properties against a number of biological targets.[9] Survey of the literature indicates that biologically active sultams may be classified as non-benzofused sultams and benzofused sultams. A number of mono cyclic and bicyclic non-benzofused sultams have been found to exhibit inhibitory activity against a range of targets including (i) γ-secretase,[10] (ii) serine protease,[11] (iii) elastase,[11] (iv) thrombin[12] and (v) matrix metalloproteinase (Figure 4.1).[13]

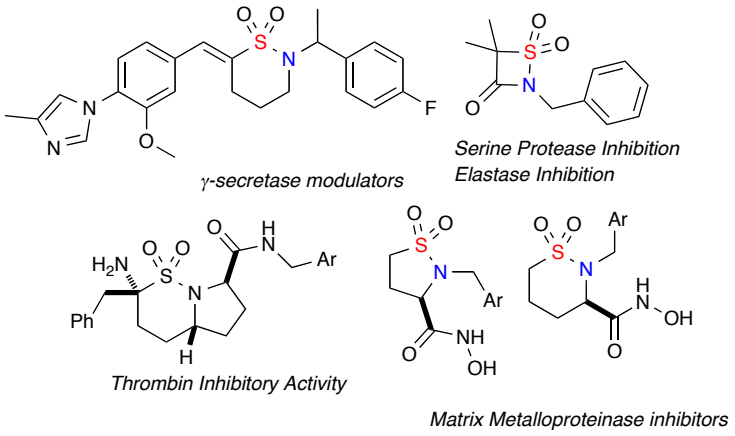


Figure 4.1

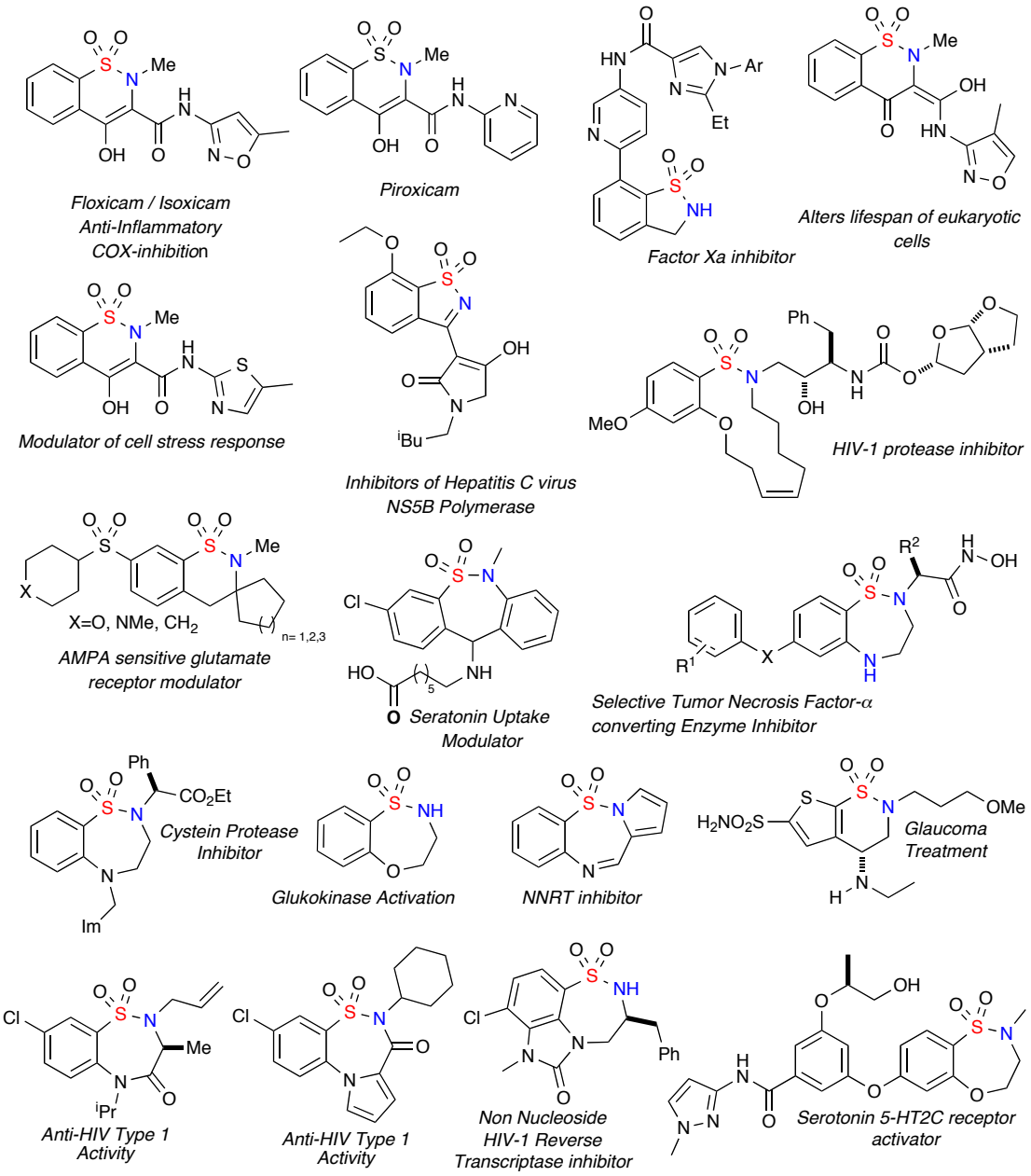


Figure 4.2

The vast majority of biologically active sultams are benzofused sultams. A number of FDA approved benzofused sultams-based drugs are currently marketed, including brinzolamide and piroxicam (also marketed as floxicam and ampiroxicam),[8]

which is testament to the utility of benzofused sultams in drug development. Additionally, an array of benzofused sultams has been found to exhibit activity against a wide spectrum of biological targets. In particular, benzothiadiazepine-1,1-dioxides and benzothiaoxazepine-1,1-dioxides have been found to display a wide biological profile including: (i) activation of glucokinase, (ii) inhibition of cysteine protease, (iii) inhibition of farnesyl transferase, (iv) COX inhibition, (v) inhibition of HIV integrase, (vi) inhibition of non-nucleoside HIV-1 reverse transcriptase, (vii) anti-leukemic activity and (viii) perturbation of AMPA receptors (Figure 4.2).[14]

4.1.2. Reaction Pairing Strategies toward Benzofused Sultam Synthesis

Several classical methodologies have been utilized for the construction of the sultam ring system including Friedel-Crafts sulfonylations,[15] Diels-Alder reactions,[16] lactamization,[17] Pictet-Spengler type cyclizations,[18] Michael additions,[19,20] Baylis-Hilman reactions,[21] [3+2] cycloadditons,[22] base-promoted Dieckman-type cyclizations[23] and S_N2 reactions[24]. More recently, a number of reports have focused on the development of transition metal-catalyzed processes for sultam syntheses and these include: (i) Cu-catalyzed cyclizations,[25] (ii) Heck reactions,[26] (iii) Rh-catalyzed cyclizations,[27] (iv) Au-catalyzed hydroaminations,[28] and (v) ring-closing metathesis (RCM).[9,16d,29] Additionally, the use of radical cyclization protocols for the synthesis of sultam skeletons have also been reported.[30] In spite of these reports, accounts of DOS strategies for the synthesis of diverse sultams are lacking in the literature.

In this regard, vinyl sulfonamides and α-bromoaryl sulfonamides[16,26,31] represent emerging chemotypes for DOS approaches to generate sultams. We have previously reported the use of these motifs as linchpins in the synthesis of sultam skeletons employing a variety of reaction pathways.[31] In studies toward the synthesis of benzofused sultams, we have identified α-bromo benzenesulfonamide linchpins that take advantage of the disparate metal-mediated reactivity of aryl bromides.[31,32] However, the use of such pathways precludes the placement of aryl halide and ene/yne functionalities as diversifiable functional groups in the target scaffolds. In contrast, α-fluoroaryl sulfonamides represent an appealing, yet highly under-explored chemotype for the generation benzofuzed sultams allowing for the use of nucleophilic aromatic substitution (S_NAr)-based reactions.[33]

The use of S_NAr reactions in organic synthesis is well documented.[34] S_NAr reactions typically involve a base, solvent and nucleophile. In addition, S_NAr reactions are well tolerant of non-electrophilic functional groups such as aryl halides as well as ene/yne systems. Furthermore, the obvious tolerance of nucleophilic functional groups such as alcohols, amides, and sulfonamides to S_NAr reactions presents interesting opportunities in the development of S_NAr-based DOS strategies. Collectively, the above factors prompted the exploration of S_NAr-based reaction pathways in a scaffold strategy employing α-fluorobenzenesulfonamides.

The synthesis of α-fluorobenzenesulfonamides entails an initial amine sulfonylation (click reaction).[35] The highly electron withdrawing nature of the SO_2

functionality, in conjunction with the α-fluoro substituent, imparts enhanced acidity/nucleophilicity of the sulfonamide NH. Presumably, the reason for this enhanced acidity is the ability of the fluorine atom at the α-position to be engaged in intramolecular hydrogen bonding with the sulfonamide N-H in similar fashion to an observation witnessed for analogous amides and amines (Figure 4.3).[36]

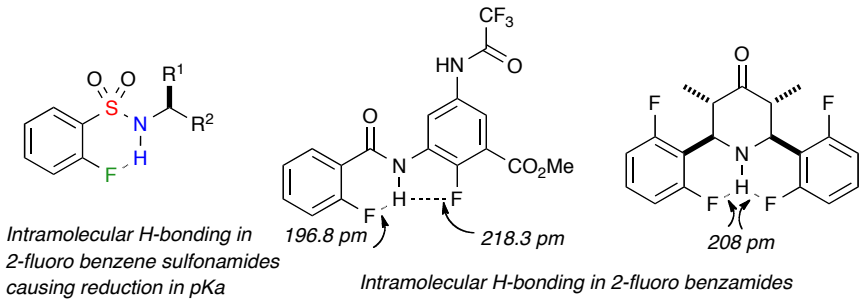


Figure 4.3

The ambiphilic nature of α-fluorobenzenesulfonamides as well as their potential pairing in complementary ambiphile pairing (CAP) strategies to produce benzofused sultams was discussed in the previous chapter. The use of orthogonal functional groups in FG-pairing strategies for accessing skeletal diversity has been discussed in chapter 1.[4] An alternative to these strategies is the pairing of reaction pathways that are orthogonal (mutually exclusive) to each other. The utility of this related approach lies in its potential to generate diverse skeletons from a single central bi-functional core without the need for the construction of an elaborate multi-functional scaffold. The reaction potential of bi-functional scaffolds can be harnessed to obtain skeletally diverse motifs by simply pairing the core scaffold with compatible synthons via suitable orthogonal reaction pathways, allowing access to skeletally

distinct motifs in a facile manner. On the other hand, utilization of all possible combinations of stereoisomeric reaction partners provides the complete matrix of possible stereoisomers, thus providing stereochemical diversity (Figure 4.4).

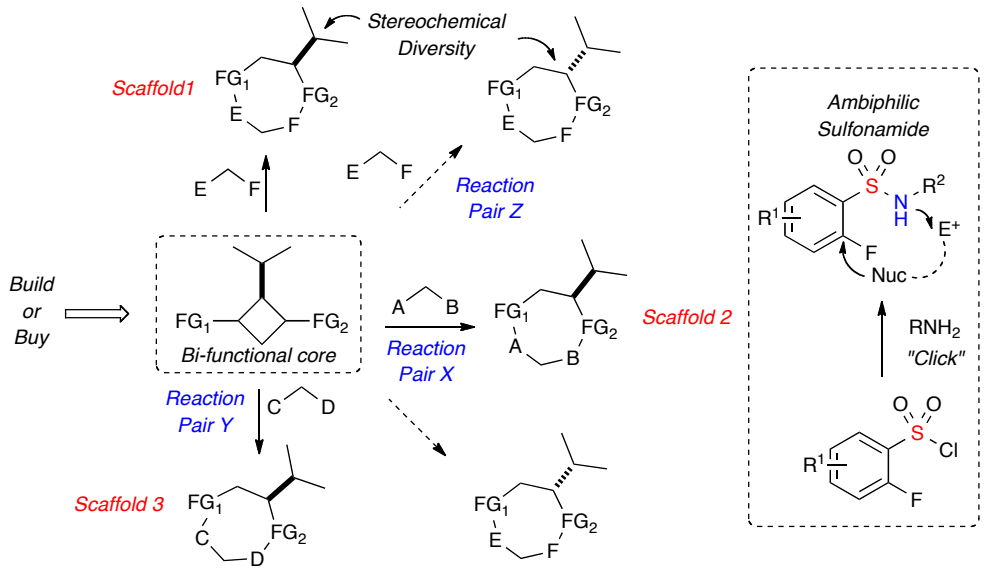
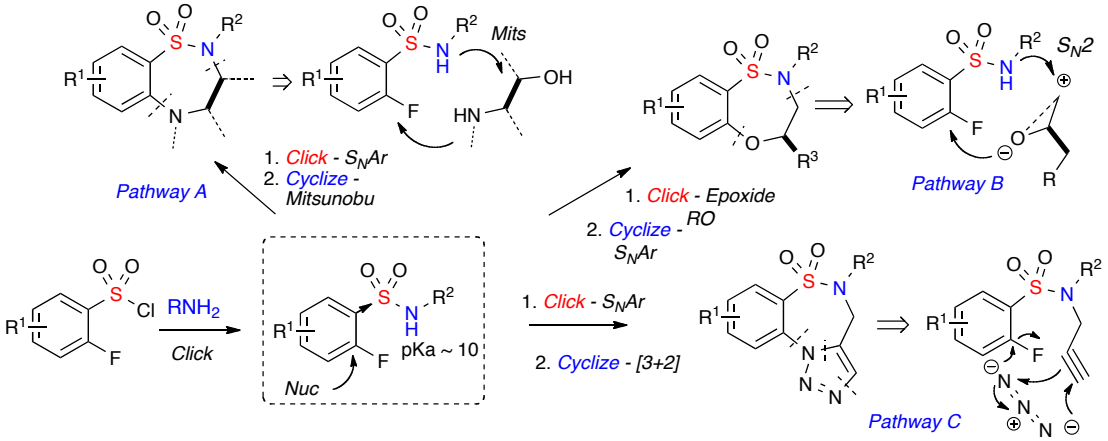


Figure 4.4

The ability of α-halo benzene-sulfonamides to undergo facile nucleophilic aromatic substitution (S_NAr) reactions,[33] along with its ambiphilic nature allow for potential pairing with compatible ambiphiles via reaction pathways orthogonal to S_NAr additions for producing benzofused sultams. Thus, three primary pathways toward sultam synthesis were envisioned, namely: (i) sequential S_NAr / intramolecular Mitsunobu cyclization (Pathway A), (ii) epoxide ring opening / intramolecular S_NAr cyclization (Pathway B) and (iii) tandem S_NAr azidation/intramolecular [3+2] cyclization (Pathway C) (Scheme 4.1).

Scheme 4.1

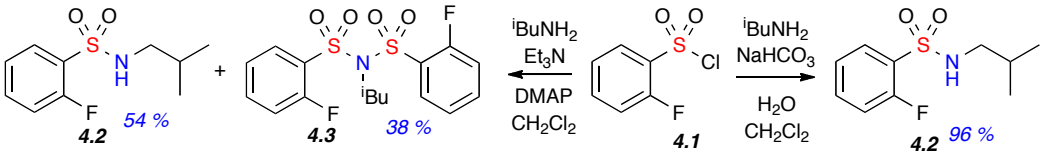


4.2. Results and Discussion

4.2.1. Nucleophilic Aromatic Substitution of α-Fluorobenzenesulfonamides

Our investigations commenced with the sulfonylation of α-fluorobenzenesulfonyl chloride (first "click" reaction) by a variety of amines under standard conditions.[37] This route afforded the desired sulfonamides in poor yields due to formation of the bis-sulfonylated product (Scheme 4.1). As mentioned previously, α-fluorobenzenesulfonamides have enhanced acidities and either the Et_3N or excess amine could deprotonate the sulfonamide, allowing for over sulfonylation. Therefore, a modified Schotten-Bauman procedure for amine sulfonylation was attempted, whereby a CH_2Cl_2 solution of the sulfonyl chloride was added dropwise to a vigorously stirring mixture of the amine and $NaHCO_3$ in a CH_2Cl_2-H_2O biphasic system.[38,39] Gratifyingly, the desired product was formed in excellent yields without the formation of the over-sulfonylated product (Scheme 4.2).

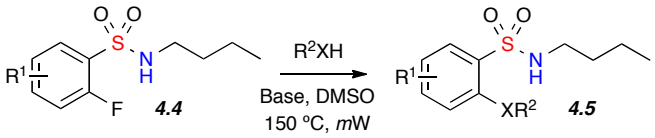
Scheme 4.2



Intermolecular addition of a variety of nucleophiles to α-fluoro benzenesulfonamides was investigated next. The addition of amines proceeded smoothly in DMF at 90 ºC, but required overnight heating for the achievement of complete conversion. Hence, the utilization of microwave irradiation (*m*W) for S_NAr addition on α-fluorobenzenesulfonamides was investigated. Gratifyingly, stirring 4-bromo-N-butyl-2-fluorobenzenesulfonamide, **4.4** (R = 4-Br) along with pyrrolidine (3.0 equiv.) under *m*W irradiation at 150 ºC in DMSO afforded desired S_NAr adduct in 30 minutes in excellent yields. Interestingly, the unsubstituted α-fluorobenzenesulfonamides required longer reaction times while bromo and chloro substituted α-fluorobenzenesulfonamides reacted in a facile manner and were high yielding. We believe that this is due to the added stabilization of the Meisenheimer complex provided by halide groups via inductive effects.[40] While acyclic amino alcohols as well as prolinols proceeded to undergo the S_NAr smoothly, nucleophlic addition of 2-(piperidin-2-yl)ethanol did not afford the desired product. The S_NAr addition of phenols required K_2CO_3 to generate the phenoxide anion to afford the desired S_NAr adduct. In comparison, alcohols required Cs_2CO_3 to generate the alkoxide to afford the desired product in satisfactory yield. While the thiophenol underwent addition affording the desired product, this addition was very low yielding

which was not surprising as thiols are known to result in the expulsion of SO_2 releasing the amine as well as the aromatic ring system (Table 4.1).[41]

Table 4.1



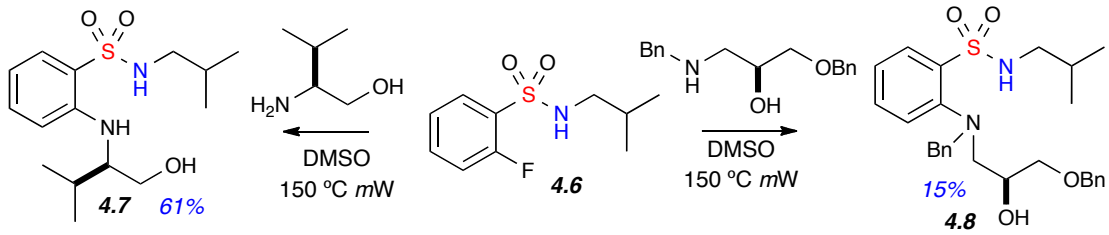
Entry	R^1	R^2XH	Base	Yield[a] **4.5** (%)
1	4-Br	Pyrrolidine	-	91
2	H	Pyrrolidine	-	74
3	4-Br	Piperidine	-	82
4	4-Br	*s*-prolinol	-	87
5	4-Br	Piperidine ethanol	-	0
6	4-Br	Allyl alcohol	K_2CO_3	42
7	4-Br	Allyl alcohol	Cs_2CO_3	74
8	4-Br	4-OMe PhOH	K_2CO_3	82
9	5-Cl	PhSH	K_2CO_3	33

[a] Isolated yields after column Chromatography [b] All reactions were carried out at 150 ºC under *m*W irradiation.

While the addition of valinol was sluggish in comparison to the addition of pyrolidine, the addition of chiral 2º amino alcohols proved to be extremely sluggish and afforded the product in extremely poor yield even with longer reaction times

(Scheme 4.3). This provided useful insight into the effect of steric hindrance on S_NAr additions of α-fluorobenzenesulfonamides.

Scheme 4.3



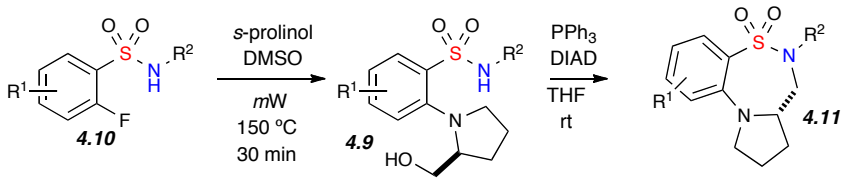
4.2.2. S_NAr - Mitsunobu Approaches To Diverse Benzofused Sultams

The Mitsunobu reaction[42] has emerged in recent times as a pivotal reaction in organic synthesis due to its broad scope, stereospecific nature and mild reaction conditions.[42,43] While the intermolecular Mitsunobu alkylation reaction has been utilized in formation of C-O bonds (esterifications), C-N bonds (sulfonamide alkylation, azidation), C-S bond (thio esterification) and C-C bonds the intramolecular Mitsunobu reactions have primarily been utilized in macrolactonizations and in the formation of N-containing heterocycles.[43] The intramolecular Mitsunobu-mediated formation of heterocycles reported in the literature involved the synthesis of tosyl / nosyl amides followed by intramolecular Mitsunobu alkylation to form 3-, 4-, 5-, 6-, 7- and 8- membered N-heterocycles as well as macrocyclic ring systems.[44,45] In spite of these successes, the syntheses of sultams utilizing intramolecular Mitsunobu alkylations have not been reported in the literature as of yet.

As mentioned above, aryl sulfonamides undergo ready Mitsunobu alkylation,[41] and hence a tandem S_NAr - intramolecular Mitsunobu strategy was envisioned for the synthesis of benzothiadazepine-1,1-dioxides utilizing amino alcohols in conjunction with the aforementioned α-fluorobenzenesulfonamides. To the best of our knowledge such a strategy has not been reported in the literature for the synthesis benzothiadazepine-1,1-dioxide scaffolds.

Accordingly, 4-bromo-2-fluoro-*N*-propylbenzenesulfonamide was allowed to undergo S_NAr addition with (*S*) - pyrrolidine methanol. Heating the sulfonamide and amine under *m*W irradiation at 150 ºC for 30 minutes in DMSO afforded the desired product **4.10** in excellent yield. We thereafter investigated use of intramolecular Mitsunobu alkylation pathways for the ring closure of the S_NAr adducts produced. Thus, addition of PPh_3 to a stirring solution of the prolinol-derived S_NAr adduct in THF (0.05 M) followed by slow addition of DIAD proceeded to quickly (10 miniutes) afford the desired tricyclic benzothiadiazepine-1,1-dioxde **4.11** in excellent yields. With the success of the aforementioned result in place, a number of benzothiadazepine-1,1-dioxide scaffolds were thus produced utilizing this protocol to furnish the desired products in good overall yields. Pleasingly, the reaction protocol was found to be general for a range of substiuents on the aromatic ring as well as the N atom (Table 4.2).

Table 4.2 S_NAr – intramolecular Mitsunobu route to benzthiaoxazepine-1,1-dioxides

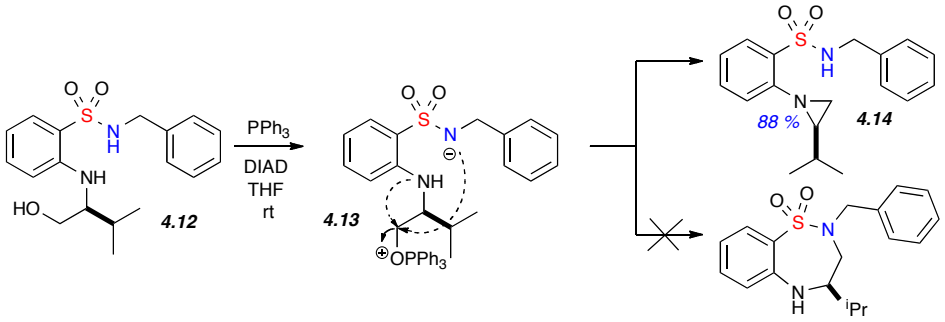


Entry	R^1	R^2	Yield[a], **4.9** (%)	Yield[a], **4.11**(%)
1	4-Br	n-Butyl	91	91
2	4-Br	Propargyl	92	81
3	4-Br	isobutyl	88	87
4	4-Br	PMB	82	77
5	4-Br	4-ClBn	86	72
6	5-Cl	cyclopropyl	87	75

[a] Isolated yields after column chromatography

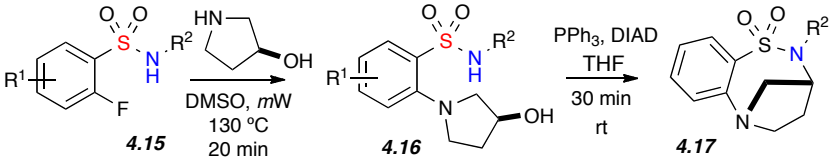
With this result in place, it was important to access skeletal diversity and it was envisaged that utilization of acyclic amino alcohols would allow access to bicyclic benzofused benzothiadazepine-1,1-dioxide scaffolds. Accordingly, (*S)* - valinol was allowed to undergo S_NAr addition to furnish the desired S_NAr adduct in acceptable yields. Subjecting this adduct to established Mitsunobu conditions did not afford the desired product, but furnished the aziridine in good yield (Scheme 4.4). Presumably the closer proximity of the amine to the phosphinoxy leaving group formed allows for aziridine formation via an S_N2 reaction.

Scheme 4.4



R-3-hydroxy pyrrolidine was utilized next for the S_NAr addition, and gratifyingly afforded the desired S_NAr adducts in excellent yields. Subjecting this adduct to Mitsunobu conditions established above pleasingly afforded the bridged benzofused sultams in acceptable yields. This sequence however required longer reaction times, presumably due to increased steric hindrance (Table 4.3).

Table 4.3.



Entry	R^1	R^2	Yield[a], **4.16** (%)	Yield[a], **4.17**(%)
1	H	2-OMeBn	91	71
2	4-Br	Propargyl	92	67
3	4-Br	cyclopropyl	82	62
4	4-Br	4-ClBn	86	72
5	5-Cl	Allyl	78	61
6	5-Cl	3,4-diCl Bn	87	58

[a] Isolated yields after column chromatography

Of notable importance, is that to the best of our knowledge, the benzofused sultams produced via this protocol represent a novel class of bridged sultams not yet represented in the literature.

4.2.3. Formal [4+3] Complementary Ambiphile Pairing Strategy to Benzoxazepine-1,1-dioxides via Epoxide Ring Opening – Ring Closing

Opportunities to expand the complementary ambiphile pairing strategy approach described in Chapter 3 were next investigated. The development of cascade reactions, which couple two or more reactions together to produce a new scaffold, is an important challenge in drug discovery and natural product synthesis.[46] Cascade or domino reactions are highly efficient pathways that allow for the synthesis of complex molecules from simple substrates and encompass a variety of transformations. Many of these cascade transformations involve the utilization of synthons, which contain either a nucleophilic or an electrophilic site.[47] In contrast, ambiphilic synthons possessing both a nucleophilic and electrophilic site, making them ideal components for cascade protocols.[48,49] Interest in the utilization of cascade reactions for the synthesis of diverse sultam scaffolds has led us to explore the titled protocol where an ambiphilic α-fluorobenzensulfonamide and an epoxide (a masked ambiphile), are combined in a cascade reaction via a CAP approach (See chapter 3). The orthogonality of sulfonamide N-H functionalities to epoxides is utilized in this reaction and ultimately an epoxide ring opening reaction is paired with an S_NAr pathway (Figure 4.5).

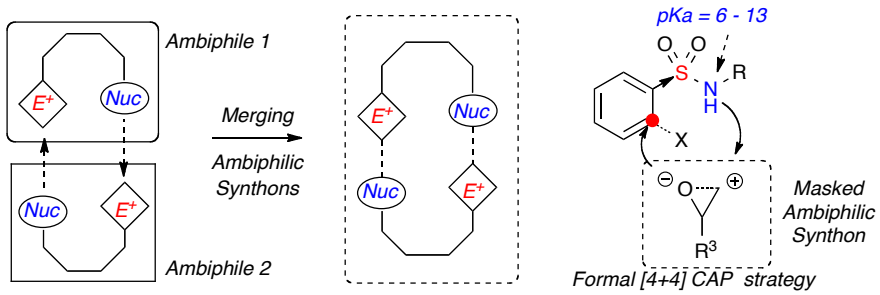
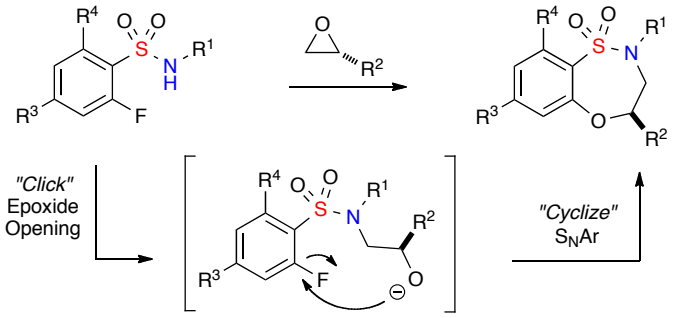


Figure 4.5

Epoxide cascade reactions have been known for over a half-century and have played a key role in the synthesis of polycyclic natural products.[50] This synthetic protocol is a powerful tool for the generation of C-O-C motifs towards the synthesis of fused polycyclic ethers possessing fascinating structure and biological properties. Despite the wide application of epoxide cascade reactions in natural product synthesis, application in the synthesis of complex small heterocycles has been utilized to a lesser degree. These reactions usually fall into two reaction types: (1) intramolecular cyclization of a nucleophilic species onto an epoxide yielding the corresponding hydroxy cyclic ether, or (2) pathways in which the opening of an epoxide with a nucleophilic species is followed by intramolecular cyclization of the released epoxide-derived alkoxide onto an electrophilic cyclization partner, vide infra. In the first type, epoxide cascades utilize a variety of organic acids to promote the cyclization,[51] whereas the second epoxide cascade protocols utilize a variety of metal catalyst to activate the electrophilic cyclization partner of the cascade. These include Au (I) cyclization with alkynes and allenes,[52] SmI_2 opening-iodocyclization[53] and cobalt-mediated cycloadditions.[54] Notably absent from the literature are methods

which combine epoxide ring-opening pathways with other pathways in a domino cascade. The development of a formal [4+3] epoxide cascade protocol which combines an epoxide ring-opening with either an S_NAr or oxa-Michael cyclization pathway for the generation of benzothiaoxazepine-1,1'-dioxides and oxathiazepine-1,1'-dioxides (Scheme 4.5) is described in this section.

Scheme 4.5

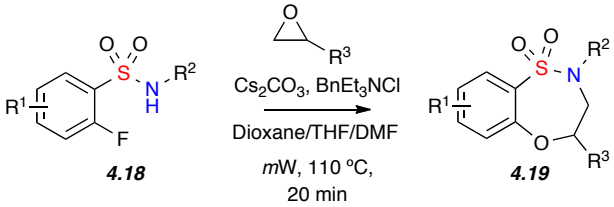


The cyclization of an in situ generated epoxy alkoxide via an intramolecular S_NAr cyclization, however, has been much more limited. A key report by Albanese and more recently by workers at Merck have demonstrated the ring opening of epoxides with α-fluorophenylsulfonamides, followed by subsequent S_NAr cyclization to give the corresponding piperazines and sultams.[55]

Initial investigation into the proposed epoxide cascade focused on the development of orthogonal reaction conditions that would initiate the ring opening of the corresponding epoxide, followed by intramolecular S_NAr cyclization to yield the desired sultam in a one-pot, domino process.[56] It was found that both the choice of solvent and base was key to the overall reaction process with dioxane essential for the

initial epoxide ring-opening step, and DMF for the S_NAr ring-closing step of the cascade. After screening a wide variety of bases, anhydrous Cs_2CO_3 produced the best overall yield and crude purity when utilized in the cascade protocol. The utilization of microwave irradiation at 110 ºC for 20 minutes was essential to obtain both high yields and crude purity in addition to a significant decrease in reaction times as conventional heating in oil bath required 20-24 hours at 150 ºC to afford the desired product, albeit with reduced yields that were on average 10-20% lower. Thus a variety of α-fluorobenzenesulfonamides and epoxides were subject to the aforementioned protocol to produce an array of benzthiaoxazepine-1,1-dioxides in excellent yields (Table 4.4).

Table 4.4



Entry	R^1	R^2	R^3	Yield[a] (%)
1	6-F	*n*Bu	CH_2OBn	73
2	6-F	*n*Bu	$(CH_2)_2CH{=}CH_2$	71
3	6-F	Allyl	(R)-CH_2OCOCH_2CN	89
4	6-F	PMB	$(CH2)_2CH{=}CH_2$	69
5	6-F	(*R*)-$CH(CH_3)Ph$	(*R*)-CH_2CO_2Et	76
6	4-Br	*n*Bu	CH_2OBn	65
7	5-Cl	Allyl	$CH_2O(CH_2)_3CH_3$	74
8	5-Cl	2-OMe-Bn	$CH_2O(CH_2)_3CH_3$	74
9	H	nBu	OBn	67
10	H	^{i}Bu	OBn	69
11	H	PMB	OBn	62
12	H	Cyclopropyl	OBn	66
13	H	Me	OBn	73
14	H	2,3-di(OMe) Bn	OBn	72

[a] Isolated yield after column chromatography.

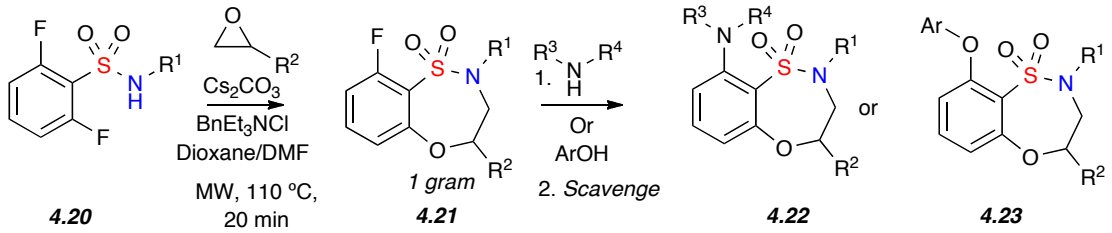
4.2.3.1. Efforts Toward Library Production.

With the aforementioned results in hand, attention was then shifted to the design and production of a medium-sized library for HTS. This was important as benzthiaoxazepine-1,1-dioxides have been found to posses myriad biological activity including (i) inhibition of histone deacetylase (for treatment of cognitive disorders such as Alzheimer's disease),[57] (ii) activation of glucokinase (for treatment of GLK mediated diseases such as diabetes)[58] and (iii) seratonin 5-HT2C activation[59] to name a few.

Studies outlined above indicates that peripheral diversity on the target benzthiaoxazepine-1,1-dioxide could be attained by variation of the substiuent on the N-atom as well as the substituents on the epoxide. It was also surmised that the highly electron withdrawing effect of the SO_2 functionality in conjunction with the placement of a fluorine atom on the aromatic ring would allow for intermolecular S_NAr additions on the aromatic ring system. In studies conducted previously, we evidenced the ability of fluorine containing aryl sulfonamides to undergo intermolecular S_NAr additions on the aromatic ring system. Therefore, with these collective results in hand, the synthesis of a 120-member library was designed. The strategy entailed the production of six core benzothiaoxazepine-1,1-dioxide scaffolds containing F-substituents on the aromatic ring in 1 gram quantities, followed by S_NAr addition of amines and phenols as nucleophiles. The development of soluble oligomeric dichlorotriazine (ODCT) as a nucleophile scavenger as well as its

utilization for the scavenging of a variety of nucleophiles, including amines, phenols and thiols was reported previously by Hanson and coworkers.[60] Therefore, it was decided to utilize ODCT as the scavenging platform in the synthesis of the benzthiaoxazepine-1,1-dioxide library. The range of nucleophiles as well core scaffolds utilized in the production of the library is summarized below (Table 4.5).

Table 4.5



R^1	R^2	Amine	Phenol
Allyl	CH_2OBn	Pyrrolidine	4-F PhOH
^{n}Bu	CH_2OPh	Piperidine	4-Me PhOH
CH_2Ph	CH_2OBu	3-(N,N-diemthyl) Pyrrolidine	4-F-2-OMe PhOH
Propargyl	*R*-CH_2OBn	3,4,5-OMe $BnNH_2$	4-OMe PhOH
α-methylBn	*R*-CH_2OAc	1-methylene methoxy pyrrolidine	
		N-Methyl toluenesulfonamide	

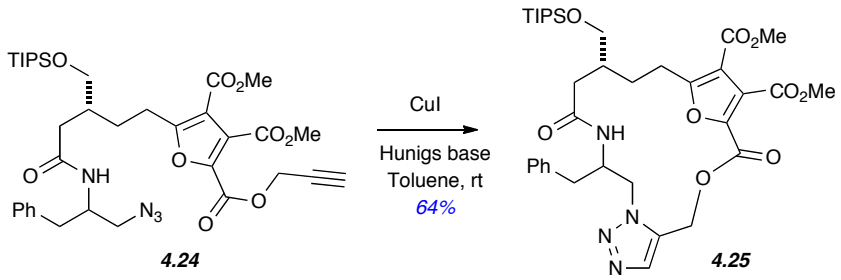
A stock solution of the scaffolds was prepared and transferred in 1 mL aliquots (50mg of scaffold) to 1 dram vials, followed by evaporation of solvents in a Genevac© parallel evaporation platform. Next, the nucleophiles (3.0 equiv.) and

Cs_2CO_3 (3.0 equiv.) were added along with DMSO and heated under *m*W irradiation at 150 ºC for 30 minutes in an Anton-Parr© parallel *m*W synthesizer. The solvent was then removed utilizing the Genevac© evaporation platform. Concurrently, a stock solution of ODCT was prepared in CH_2Cl_2 and added to the reaction vials such that there was a 4-fold excess of the scavenger to allow for complete scavenging of the nucleophiles as well as any DMSO and subsequently subjected to under *m*W irradiation at 50 ºC for 30 minutes. The reactions were then filtered via a silica SPE cartridge to furnish the desired products.[61]

4.2.4. Intramolecular Alkyne-Azide [3+2] Huisgen Cycloadditions Toward Small Molecule Synthesis for High Throughput Screening.

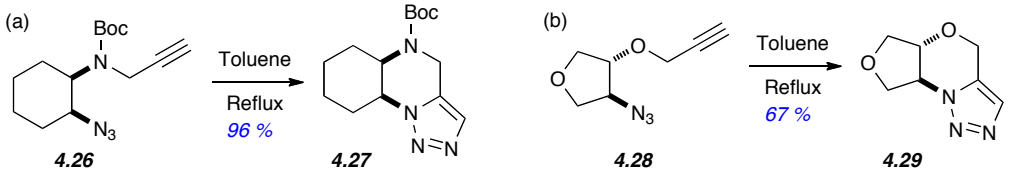
Azide-alkyne [3+2] Huisgen dipolar cycloaddition reactions have evolved rapidly since its discovery and its use in the synthesis of biological probes is well represented in the literature.[62] In spite of its popularity and widespread use, intramolecular azide-alkyne [3+2] Huisgen dipolar cycloaddition reactions remain appreciably under-explored and under utilized. Zhu and coworkers have reported the use of the aforementioned pathway for the synthesis of macrocycles.[63] Schreiber and coworkers, as well as Macurelli and coworkers have utilized intramolecular alkyne-azide cycloaddition in DOS strategies for the synthesis of diverse macrocyclic molecules (Scheme 4.6).[64]

Scheme 4.6



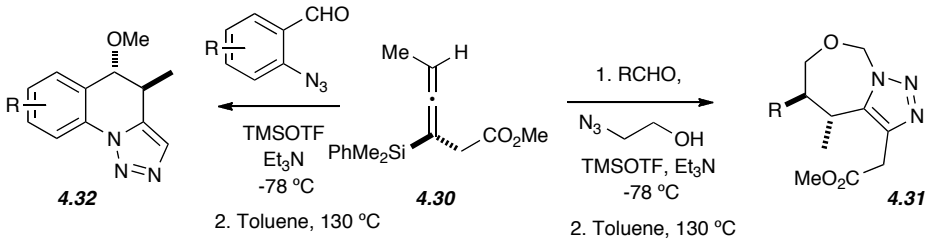
In spite of these reports, the use of azide-alkyne [3+2] Huisgen dipolar cycloaddition reactions as a ring closure mode in the synthesis of non-macrocyclic molecules is limited. Datta and coworkers have reported the use of intramolecular Huisgen cycloaddition approach for the synthesis of a number of triazole containing cyclic amines. However these were limited to the synthesis of 6-member ring systems (Scheme 4.7).[65]

Scheme 4.7.



More recently, Panek and coworkers have reported the use of azide-alkyne [3+2] Huisgen for the synthesis of benzofused triazole containing cyclic ethers. Thus, 2-azido benzaldehydes were subjected to propargylation utilizing allenyl silanes followed by intramolcular [3+2] dipolar cycloaddition to furnish the benzofused triazole containg tricyclic ring system **4.32** (Scheme 4.8).[66]

Scheme 4.8.

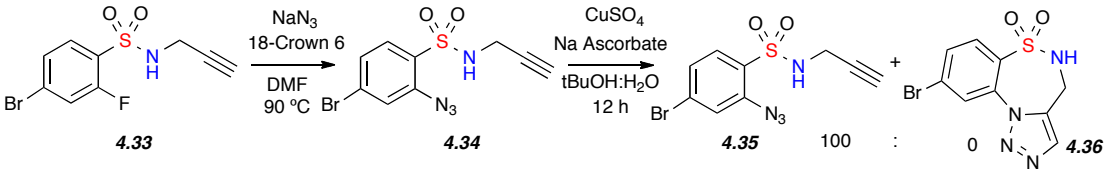


4.2.4.1. One Pot Sequantial S_NAr – Intramolecular [3+2] Alkyne Azide Cycloaddition Route toward Tricyclic Benzofused Sultams

In spite of the success of [3+2] Huisgen Cycloadditions, their use in the generation of sultam scaffolds have not been reported to date. The S_NAr azidation of the propargyl amine-derived α-fluorobenzenesulfonamide was therefore explored with the aim of affecting an intramolecular [3+2] Huisgen cycloaddition to afford tricyclic triazole containing benzofused sultams.

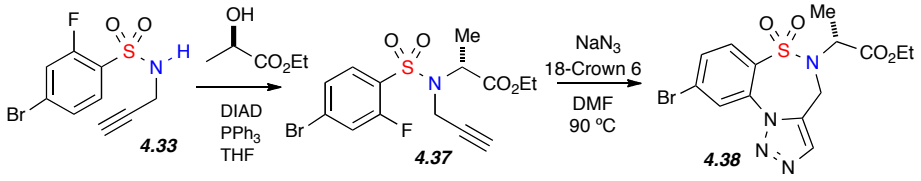
Accordingly, NaN_3 was added to a stirring solution of 4-bromo-2-fluoro-N-(prop-2-yn-1-yl)benzenesulfonamide **4.33** in DMF at 90 ºC in the precence of 18-crown-6 for 8 hours to afford the desired 2-azido-4-bromo-N-(prop-2-yn-1-yl)benzenesulfonamide in good yield, **4.34** and was subsequently subjected to typical click conditions whereby **4.34** was stirred overnight in ^tBuOH / H_2O mixture in the precence of $CuSO_4$ and sodium ascorbate. Disappointingly, these conditions failed to afford the desired ring closed sultam product **4.36** (Scheme 4.9)

Scheme 4.9



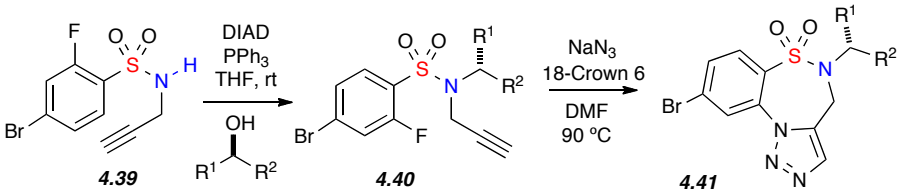
It was concluded that in the above case, the propargyl group is placed away from the azide assisted by the intramolecular H-bonding described previously (Figure 4.3, pg 122). Therefore, it was envisioned that substituting a large group at the N atom would force the alkyne to be in closer proximity to the azido functionality. Accordingly an intermolecular Mitsunobu alkylation reaction utilizing L-ethyl lactate was carried out on sulfonamide **4.33** to furnish the desired product **4.37** in good yield. Thereafter, NaN_3 (3.0 equiv.) was added to a stirring solution of**4.37** and 18-crown-6 in DMF and heated at 90 ºC for 6 hours. We observed disappearance of starting material and the appearance of the two distinct products, which over time converged to a single product. Upon isolation, the product was found to be the tricyclic triazole-containing product **4.38** that had undergone an intramolecular [3+2] Huisgen cycloaddition ring closure following intermolecular S_NAr azidation. To the best of our knowledge this represents the first report of a one-pot tandem S_NAr-intramolecular [3+2] Huisgen cycloadditon for the synthesis of benzofused sultams (Scheme 4.10). Furthermore, to the best of our knowledge the heterocycle system produced here has not been reported prior to this account.

Scheme 4.10



The substrate scope of the reaction was next investigated. Accordingly, a series of 3° α-fluorobenzenesulfonamides were prepared via Mitsunobu alkylation of 4-bromo-2-fluoro-N-(prop-2-yn-1-yl)benzenesulfonamide **4.33** with a variety of 1° and chiral 2° alcohols. These adducts were then subjected to azidation conditions established above and proceeded to afford the desired ring closed tricyclic benzofused triazole containing sultam **4.41** as a yellow solid in acceptable yield (Table 4.6).

Table 4.6



Entry	R^1	R^2	Yield. 4.41[a](%)
1	Me	CO_2Et	52
2	H	$CH(^iPr)NHBoc$	61
3	H	4-CF_3OPh	73
4	H	4-FPh	59
5	H	3-ClPh	53

[a] Isolated yield after column chromatography.

The reaction was found to tolerate a variety of substituents including esters and boc-protected amines, as well as a variety of benzyl groups. The success with NBoc groups as well as esters was important, as this would allow for diversification in the synthesis of libraries. Furthermore, the ability to place chiral centers at different positions was important from a DOS perspective as it allows for accessing stereochemical diversity. Overall, a one-pot S_NAr-Huisgen [3+2] cycloaddition protocol has been developed for the production of novel benzo[*f*][1,2,3]triazolo[5,1-*d*][1,2,5]thiadiazepine 6,6-dioxides. Currently, the compounds produced are being submitted for biological screening.

4.3. Summary and Future Outlook

In conclusion, an orthogonal reaction pairing strategy based on the ability of α-fluorobenzenesulfonamides to undergo facile nucleophilic aromatic substitution (S_NAr) reactions to generate diverse polycyclic benzofused sultams has been developed. Several reaction pathways have been developed including: (i) S_NAr-intramolecular Mitsunobu alkylation, (ii) sulfonamide epoxide ring opening-S_NAr ring closing and (iii) one pot tandem S_NAr – intramolecular alkyne – azide [3+2] Huisgen cycloadditions to produce an array bicyclic, tricyclic and bridged benzofused sultams. The production of a medium-sized library utilizing the epoxy cascade protocol has also been described (Figure 4.6).

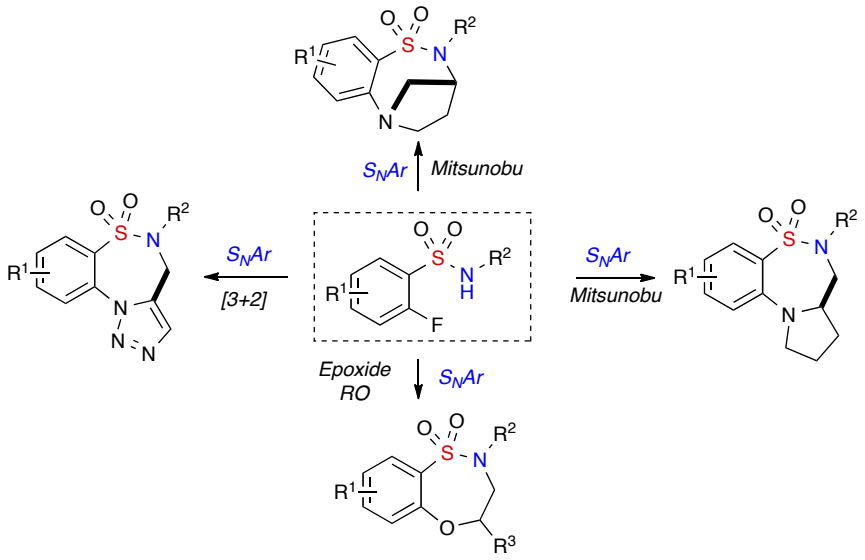


Figure 4.6

Overall, the work described in this chapter demonstrates the ability to construct to obtain skeletally diverse motifs by simply pairing the core scaffold with compatible synthons via suitable orthogonal reaction pathways, which provide access to skeletal diversity in a facile manner by harnessing the ambiphilic nature of α-fluorobenzenesulfonamide bi-functional scaffolds. The utilization of chiral SM thus allowing entry to stereochemical diversity has also been described in this chapter. Future work should focus on developing other reaction manifolds as well as using all possible combinations of stereoisomeric SM to produce the complete matrix of stereoisomers possible .

The facile nature of the chemistry as well as the novelity of the scaffolds produced makes it highly amenable for utilization in DOS approaches as well as library production. The ability to generate multiple scaffolds from a single sulfonamide SM also makes these methodologies highly amenable for adaptation with continuous flow platforms.

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Chapter 5

Click, Cyclize, Click: A DOS Strategy Toward the Facile Synthesis of Diverse Benzofused Sultam Libraries.

5.1. Introduction

The development of methods and related strategies for producing core scaffolds is crucial for diversity oriented synthesis (DOS) based strategies.[1,2] The advent of "rational" diversity oriented synthesis whereby so-called "privileged structures" are utilized as core scaffolds in DOS approaches for the discovery of biologically active probe molecules has presented opportunities as well as challenges in this regard.[3,4] This chapter describes a DOS approach termed "click, cyclize, click" for production of diverse benzofused sultams based primarily on benzothiaoxazepine-1,1-dioxide cores.

Sultams (cyclic sulfonamides), have emerged as an important class of molecules due to the exhibition of biological activity against an array of biological targets as discussed in the previous chapter.[5,6] Within this class of heterocycles, several subclasses including: (i) benzothiaoxazepine-1,1-dioxides (vide infra) and (ii) benzothiadiazepine-1,1-dioxides have displayed disparate biological activity.[7] Each of these subclasses therefore presents opportunities in rational DOS approaches in the production of probe compound collections for HTS against a variety of biological targets.

The need for diverse benzofused sultam cores for utilization in DOS approaches prompted the investigation of strategies that would allow facile access to these scaffolds. In this regard α-fluorobenzenesulfonyl chlorides represent an emerging building block synthon.[8] The electron withdrawing nature of the SO_2

functionality imparts enhanced electrophilicity at the β-carbon atom and α-fluorobenzenesulfonyl chlorides may therefore be viewed as bis-electrophiles. Therefore, it follows that pairing of these bis-electrophilic synthons with bis-nucleophiles in complementary fashion would afford benzofused sulfur heterocycles in a highly efficient manner. Amino alcohols in particular are highly attractive in this respect due to a number of reasons: (i) formation of diversifiable sulfonamide N-H, (ii) ease of synthesis and (iii) commercial availability. On the other hand, pairing of 1,2-amino alcohols with the sulfonyl chloride affords access to benzothiaoxazepine-1,1-dioxides (Figure 5.1).

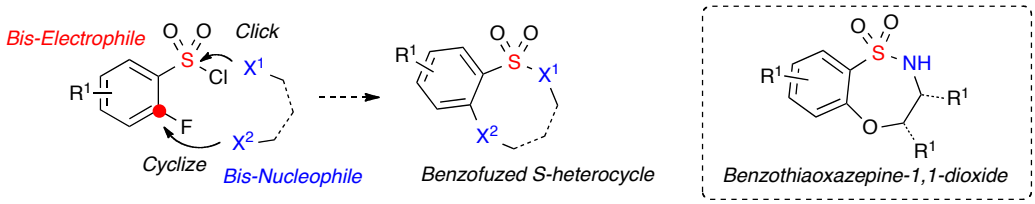


Figure 5.1

Benzoxazepine-1,1-dioxide scaffolds have been found to display biological activity against a myriad biological targets. Biological activity uncovered to date include (i) inhibition of histone deacetylase (for treatment of cognitive disorders such as Alzheimers desease),[9] (ii) activation of glucokinase (for treatment of GLK mediated diseases such as diabetes),[10] (iii) serotonin 5-HT2C activation,[11] (iv) histamine H3 receptor modulation (for treatment of Alzheimers disease, attention deficit hyperactivity disorder - ADHD),[12] (v) inhibition of MDM2-p53 (for potential use as anti-cancer agents),[13] (vi) sodium-proton exchange inhibitors (useful for

development of medication for treating cell proliferative disorders and diabetes),[14] (vii) bradykinin B1 receptor antagonist (for treating Alzheimer's disease),[15] (viii) AMPA receptor agonist[16] and (ix) metalloproteinase inhibition (Figure 5.2). [17] The aforementioned disparate biological profile of benzthioxazepine-1,1-dioxide scaffolds therefore presents opportunities for a rational DOS approach in the construction of libraries for probing chemical space.

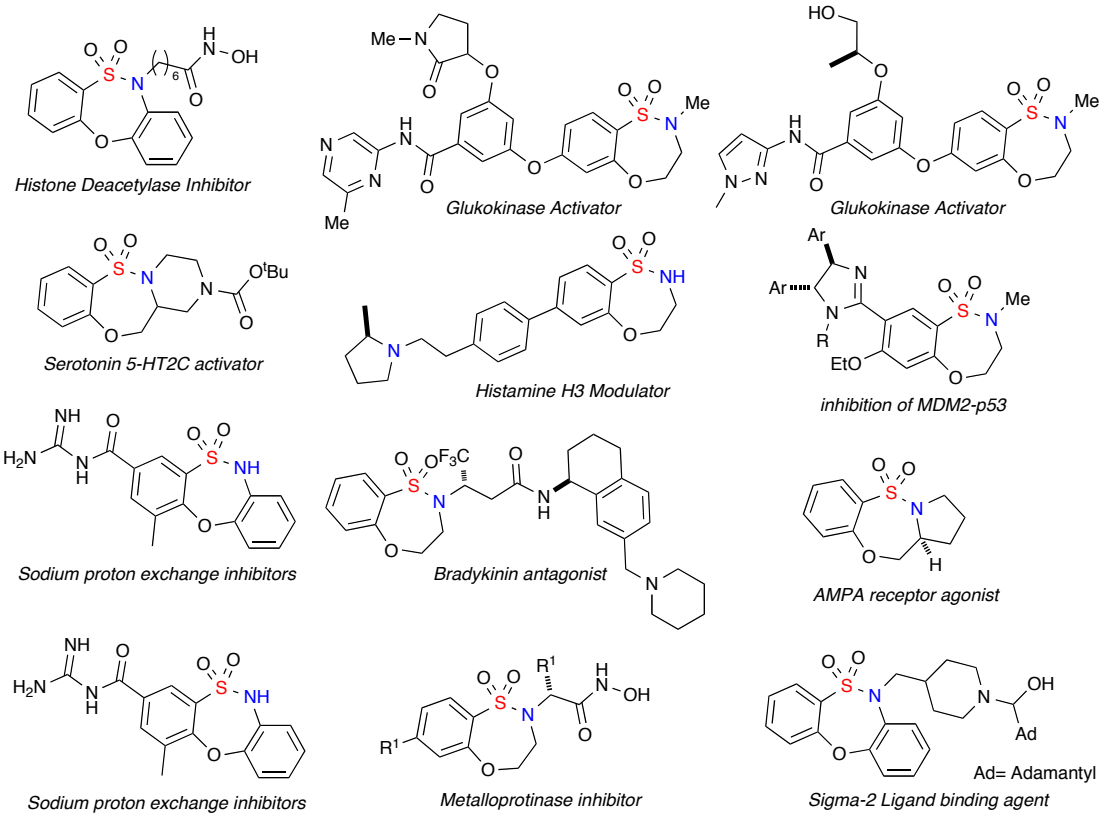


Figure 5.2

5.1.1. Click, Cyclize, Click: A DOS Strategy based on Benzothiaoxazepine-1,1-dioxides

The scaffold strategy devised for the work reported in this chapter commences with the pairing of amino alcohols with α-fluorobenzenesulfonyl chlorides via an amino alcohol sulfonylation (click reaction) followed by subsequent intramolecular S_NAr *o*-arylation to afford benzofused sultams bearing a 2° sulfonamide functionality.[18] Utilization of a variety of post-cyclization reactions at the sulfonamide N-H as well as at the periphery of the aromatic ring allows for the production of benzothiaoxazepine-1,1-dioxides libraries with appendage diversity. Stereochemical diversity is obtained by utilizing an array of chiral amino alcohols used in the first click reaction as well as in a variety of post-cyclization reactions. Skeletal diversity can be achieved employing structurally distinct amino alcohols Overall, this strategy allows for the synthesis of a variety of benzofused sultams via a 3-step protocol (Figure 5.3).

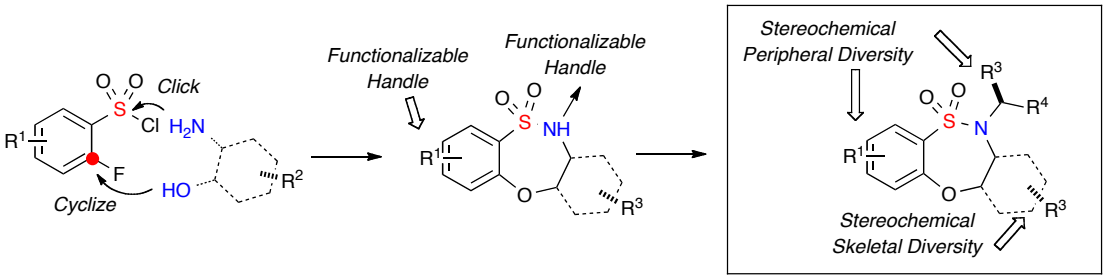
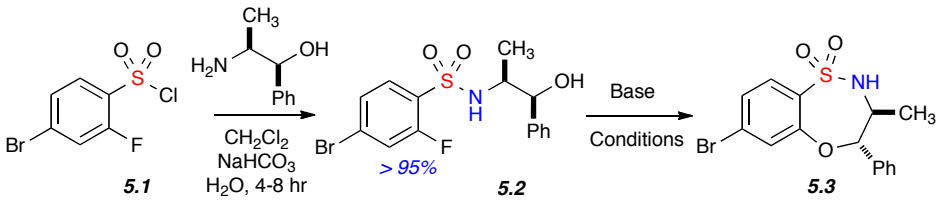


Figure 5.3

5.2. Results and Discussion

Investigations commenced with the production of a series of β-hydroxy α-fluorobenzenesulfonamides. Thus, TBS-protected amino alcohols were prepared under standard conditions[19] and subjected to sulfonylation with 4-bromo-2-fluoro benzenesulfonyl chloride in the presence of Et_3N and DMAP utilizing CH_2Cl_2 as the solvent. The desired products were realized in less than optimal yields (<70%), mainly due to the over sulfonylation of the silyloxy protected amino alcohols. It was concluded that the enhanced the acidity of the sulfonamide N-H (as discussed in the previous chapter) results in deprotonation by Et_3N thus allowing for a second sulfonylation to take place. Furthermore, sulfonylations of amino alcohols under typical sulfonylation conditions mentioned above require protection of the hydroxy group. Recently Tidor and co-workers have reported the utilization of a modified Schotten-Bauman procedure for sulfonylation of hydroxy amines without the need for protection of the hydroxy group.[20] This protocol was utilized for the first click reaction, whereby addition of 4–bromo-2-fluoro benzene sulfonyl chloride to a vigorously stirring solution of norephedrine (2 equiv.) and $NaHCO_3$ in 2:1 CH_2Cl_2 / H_2O for 4-8 hours gratifyingly provided the desired 2-hydroxy sulfonamide product **2** in excellent yields. A simple acid wash with 10% HCl removed all traces of the amino alcohol SM (Scheme 5.1).

Scheme 5.1



Thereafter conditions for the intramolecular S_NAr cyclization of the above product was probed. Due to the success of the intramolecular *O*-arylation discussed previously (see Chapter 4), efforts commenced with heating a DMF solution of **5.2** (0.1M) in the presence of Cs_2CO_3 at 130 ºC under microwave (*m*W) irradiation for 30 minutes and pleasingly afforded the desired product in 99% yield. Curiously, use of DMSO afforded the product in reduced yields. In spite of the success of Cs_2CO_3, its insolubility in organic solvents creates a stumbling block for use in high throughput protocols such as liquid handling systems and continuous flow systems. Therefore the use of alternate bases were looked into and disappointingly, Et_3N, DIPEA and DBU failed to afford any product. This latter result presumably is due to the relatively weakly basic nature of Et_3N, DIPEA and DBU (Table 5.1).

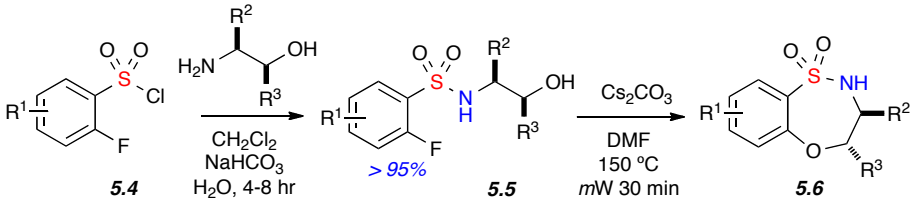
Table 5.1.

Entry	Solvent	Base	Yield[a,b] (%)
1	DMF	Cs_2CO_3	95
2	DMSO	Cs_2CO_3	61
3	DMF	Et_3N	0
4	DMF	DIPEA	0
5	DMF	DBU	0

[a] All reaction were carried out at 130 ºC under *m*W irradiation for 30 miniutes. [b] Isolated yields after column chromatography.

With these results in hand Cs_2CO_3 (3 equiv.) was employed for affecting the S_NAr-based cyclization. In this regard, reaction scales exceeding 200 mg required heating at 150 ºC to achieve complete conversion. With optimization of the route in hand, a 16-member sub-library of benzothiaoxazepine-1,1-dioxide scaffolds was subsequently prepared in 1-1.5 gram scale. The optimized reaction protocol was found to tolerate a variety of halide substituents on the aromatic ring as well as a variety of substituents on the amino alcohol portion and proceeded to afford the desired product as free flowing solids in excellent yields (Table 5.2, Figure 5.4).

Table 5.2.



Entry	R^1	R^2	R^3	**5.5**[a] (%)	**5.6**[a](%)
5.6a	4-Br	Me	H	99	99
5.6b	4-Br	Ph	H	93	89
5.6c	4-Br	^{i}Pr	H	96	87
5.6d	4-Br	^{i}Bu	H	97	94
5.6e	4-Br	Bn	H	89	83
5.6f	4-Br	Me	Ph	92	95
5.6g	4-Br	Me	Ph	94	82
5.6h	5-Cl	^{i}Pr	H	91	89
5.6i	5-Cl	^{i}Bu	H	88	91
5.6j	5-Cl	Bn	H	92	93
5.6k	3-Cl	Me	H	87	89
5.6l	6-F	^{i}Bu	H	93	88
5.6m	6-F	Me	Ph	94	92
5.6n	4-F	^{i}Bu	H	95	93
5.6o	4-F	^{i}Pr	H	97	94
5.6p	4-F	^{i}Bu	H	94	91

[a] Isolated yield after purification via column chromatography.

Figure 5.4

However, it must be noted that multi-gram the scale up of these reactions required a batchwise approach since the reactions were carried out at 0.1 M concentrations and hence the required solvent volumes reached the limit imposed by the Biotage© personal chemistry *m*W system utilized for this process. Scale-up was therefore achieved via sequential batch-wise mode employing 400 mg quantities per *m*W run. The placement of halide functionalities was important for a number of reasons including: (i) aryl fluorides in conjunction with the SO_2 functionality allows for employment of S_NAr-based diversification pathways and (ii) aryl bromides and chlorides allow for utilization of transition metal catalyzed diversification pathways.

Coupled with the acidic 2º sulfonamide functionality, all of the above mentioned molecules **5.6a – 5.6p** represent bi-functional scaffolds with two points of diversification (Table 5.2). The ability to place halides at C6, C4, C3 coupled with the presence of the C7, C8 static diversity points and the reactivity at N atom collectively provides a molecular scaffold that is able to cover a remarkable amount of chemical space that could potentially interact with biological systems, thus enhancing the chance for uncovering biologically active benzoxthiazepine-1,1-dioxides (Figure 5.5).

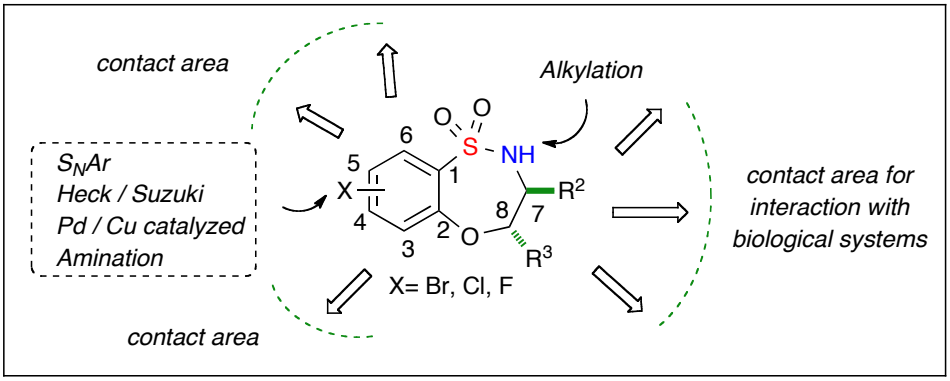


Figure 5.5

5.2.1. Mitsunobu Approaches Toward Accessing Stereochemical Diversity

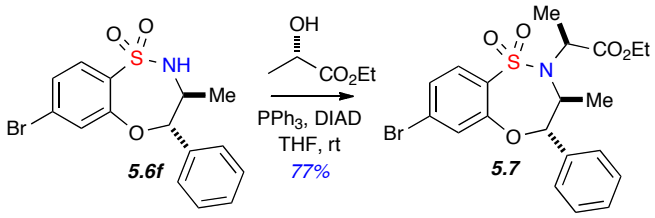
Accessing stereochemical diversity is a highly important facet of DOS and is based upon the notion that increasing relative orientations of the elements interacting with macromolecular systems will result in the increase the chance of such potential interactions. Reaction pathways that are stereospecific are highly important in his regard as it allows access to the full spectrum of possible stereoisomers. Therefore identification of functional groups and compatible reaction pathways capable of undergoing stereospecific reactions are crucial in this regard.

The Mitsunobu reaction assumes much importance in this respect due to its stereospecific nature.[21] Additionally, the stability and relative abundance of chiral hydroxy-containing compounds increases the importance of the Mitsunobu reaction in DOS approaches. In spite of its potential, the utilization of the Mitsunobu reaction for generating stereochemical diversity seems to be limited to the construction of

building blocks via the Fukuyama protocol.[22,23] On the other hand, sulfonamides are well known for undergoing Mitsunobu alkylations.[22] However no reports exist of the utilization of Mitsunobu pathways for the alkylation of of the sulfonamide N-H of sultams. The utilization of intermolecular Mitsunobu pathways for asscessing stereochemical diversity employing the acidic sulfonamide N-H of benzofused sultams is herein presented.

Efforts commenced with the addition of DIAD to a stirring solution of **6f**, L-ethyl lactate and PPh_3 in THF. The reaction was found to go to completion in 2 hours and gratifyingly afforded the desired alkylated product in 77% yield (Scheme 5.2).

Scheme 5.2



With this result in hand, a number of benzthiaoxzepine-1,1-dioxides were subjected to the Mitsunobu alkylation conditions above with an array of 1° chiral alcohols as well as optically pure 2° alcohols and gratifyingly forded the product in good to excellent yields. Particularly pleasing was the fact that NBoc amino alcohols afforded the Mitsunobu product in excellent yields. Of noteworthy mention is that use of Mitsunobu pathways not only allows for installation of multiple sterocenters,

but produces compounds that are of bi-functional nature themselves and are primed for utilization as scaffolds in library generation (Figure 5.6).

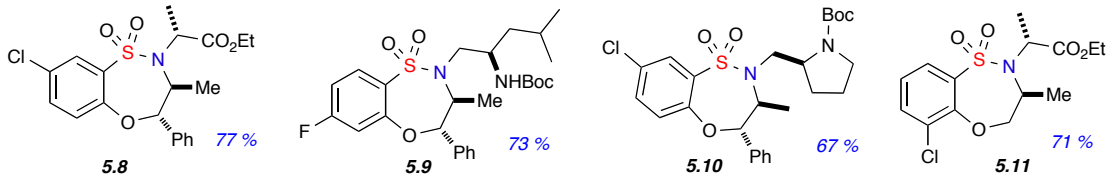


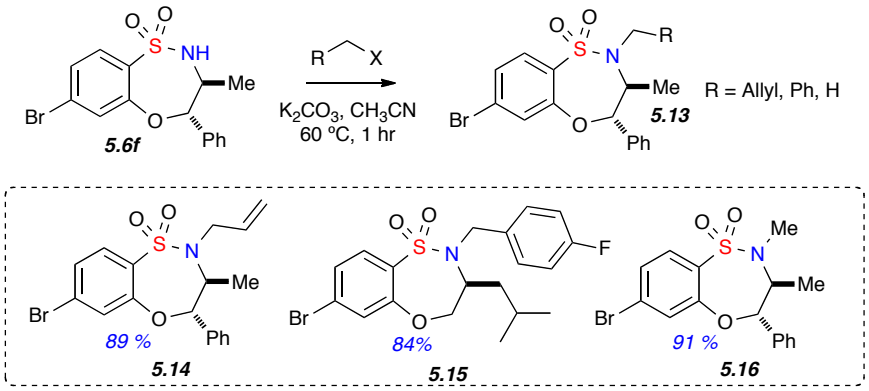
Figure 5.6.

Notably, these intermolecular Mitsunobu alkylations went to completion in 2-4 hours at room temperature whereas alkylation of sulfonamides under Mitsunobu conditions typically require overnight stirring. This might suggest that the 2º sulfonamide NH functionality of sultams have enhanced acidity compared to the corresponding acyclic analogs.

5.2.2. Exploration of Other Diversification Pathways

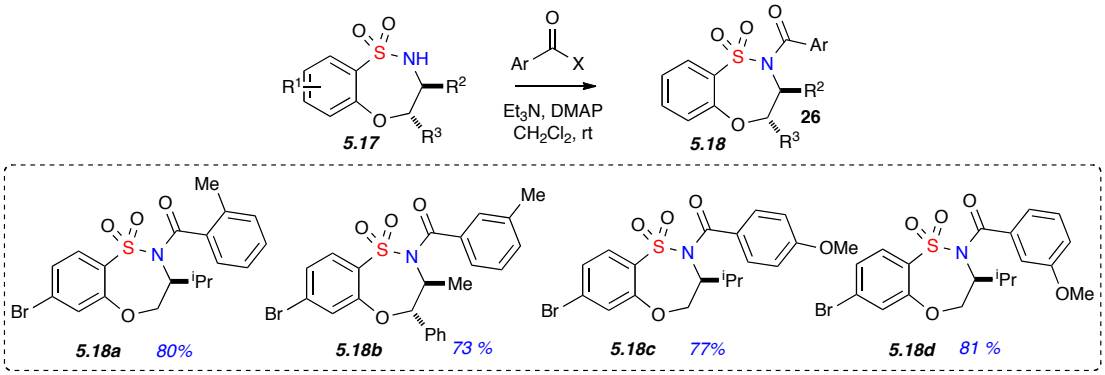
With the Mitsunobu alkylation results in hand, we proceeded to further investigate the reactivity of the 2º sulfonamide N-H functionality for the production libraries. We first investigated the alkylation of the sulfonamide N-H and addition of allyl bromide (1.5 equiv.) to a stirring solution of **5.6f** in K_2CO_3 in CH_3CN followed by subsequent stirring for 1 hour at 60 ºC gratifyingly afforded the allylated product in excellent yield. **5.6f** was also found to under go facile benzylation as well as methylation to afford the desired product in excellent yields all as white solids (Scheme 5.3).

Scheme 5.3



Acyl sulfonamides have been found to exhibit against a range of biological activity including: (i) anti-proliferative activity,[24] (ii) anti-tumor activity[25] and (iii) protease inhibitors of the hepatitis C virus full-length NS3 (protease-helicase/NTPase),[26] to name a few and hence have received considerable attention in drug development. With this in mind the acylation of the free sulfonamide N-H containing benzofuzed sultams was examined. Given the acidity of this functionality it was concluded that Et_3N could be sufficiently basic for sulfonamide deprotonation. Accordingly, treatment of **5.6f** with Et_3N in a stirring CH_2Cl_2 solution containing DMAP gratifyingly afforded the desired acyl bezothiaoxazepine-1,1-dioxide **5.13** in excellent yields. Curiously, this report represents the first reported synthesis of acyl sultams to the best of our knowledge (Scheme 5.4).

Scheme 5.4

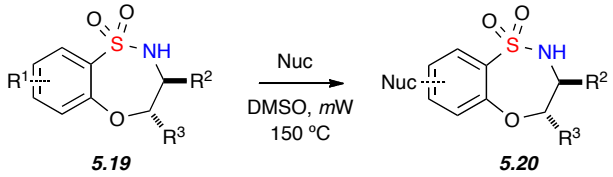


With the aforementioned successes in hand, we next investigated the implementation of diversification on the aromatic ring system of the core scaffold as this would allow for the installation of macromolecule interacting elements on the left hand portion of the scaffold (Figure 5.5, page 165). Upon examination of the scaffold system it was concluded that the electron withdrawing nature of the SO_2 functionality might allow for S_NAr-based diversification pathways.

Accordingly, a DMSO solution of **5.6m** (1M) was heated in the presence of pyrrolidine (3 equiv) under *m*W irradiation at 150 ºC for 35 minutes to afford the desired S_NAr adduct in good yield. This S_NAr reaction was found to work well for a variety of 1º and 2º amines as well as alcohols furnishing the desired product in good yields. Differing placement of the fluorine atom on the aromatic ring from C-2 to C-4 allows for covering a considerable amount of space. Pleasingly, the reaction was found to work well for amines as well as alcohols, although alcohols took with longer reaction times. Utilization of conditions established above, a number of 1º and 2º amino alcohols were found to yield the desired product in good yields. Significantly,

the ability to utilize chiral amino alcohols for S_NAr additions on the core scaffold provides access to stereochemical diversity on the left hand portion of the core molecule (Table 5.3).

Table 5.3.



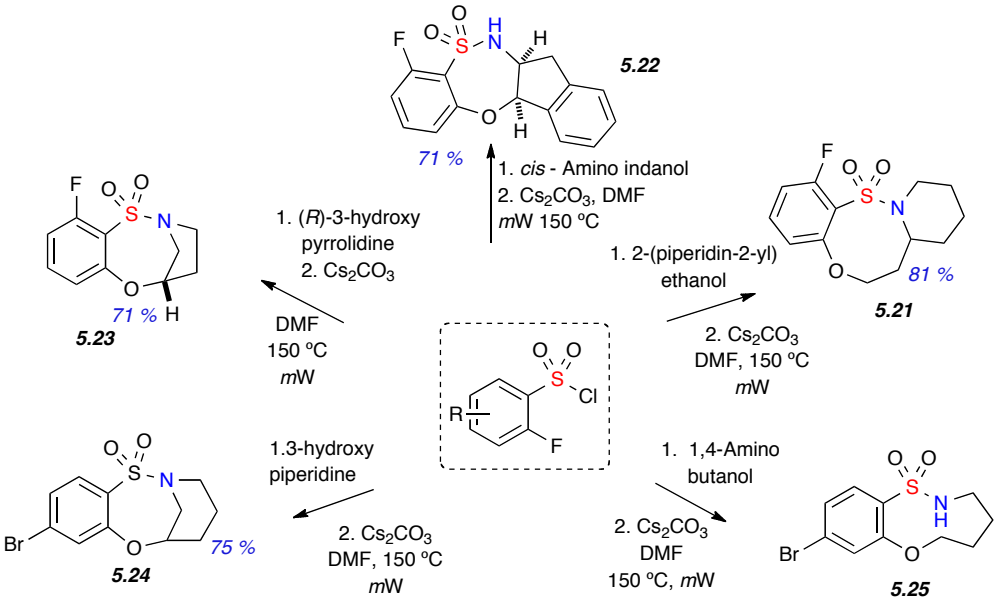
Entry	R^1	R^2	R^3	Nucleophile	Yield[a] (%)
1	2-F	H	^{i}Bu	^{i}Bu-NH_2	72
2	2-F	H	^{i}Bu	Pyrrolidine	77
3	2-F	H	^{i}Bu	Piperidine	79
4	2-F	Ph	CH_3	Allyl NH_2	69
5	4-F	H	^{i}Bu	R-3-hydroxy pyrrolidine	71
6	4-F	H	^{i}Bu	Allyl OH	52

5.2.3. Accessing Skeletal Diversity

With the above results in hand, access to skeletal diversity was next explored. We envisioned that this could be achieved by employing amino alcohols with diverse architectures. While polycyclic scaffolds could be obtained by utilizing cyclic amino alcohols, different ring sizes can be attained via usage of 1,2- 1,3- and 1,4- amino alcohols. Therefore an array skeletally diverse amino alcohols were sulfonylated with

4-bromo-2-fluorobenzenesulfonyl chloride and 2,6-difluorobenzenesulfonyl chloride employing the modified Schotten-Bauman[27] procedure utilized previously to produce the desired sulfonamides. Subjection of these sulfonamides to the optimized cyclization conditions gratifyingly afforded the desired compounds as free flowing solids in excellent yields. With this strategy an array of diverse scaffolds including 6,7,5,6-fused tetracyclic systems (employing *cis* 1,2-aminoindanol), 6,7,6- (with piperidine ethanol) and 6,9-bicyclic systems (with 1,4-aminobutanol) as well as tricyclic bridged molecules (3-hydroxy pyrrolidine and 3-hydroxy piperidine) were accessed (Scheme 5.5).

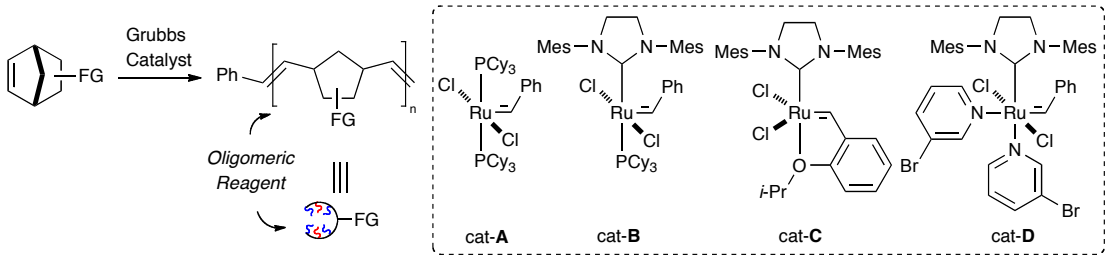
Scheme 5.5



5.2.4. Utilization of Soluble High Load Soluble Oligomeric Triphenylphosphine in Library Generation

Soluble polymer-supported reagents and scavengers have emerged in recent years as a means of utilizing solution phase reaction kinetics with all the advantages of their solid phase counterparts.[28] Our group has been involved in the development of a number of high load reagents via ROM polymerization techniques to provide supported reagents possessing solubility profiles that are tunable and which can be used in parallel solution phase synthesis. Reagent generation involves the polymerization of strained norbornenyl-tagged functional groups catalyzed by Grubbs ruthenium alkylidene metathesis catalysts to produce oligomeric reagents and scavengers (Scheme 5.6).[29]

Scheme 5.6

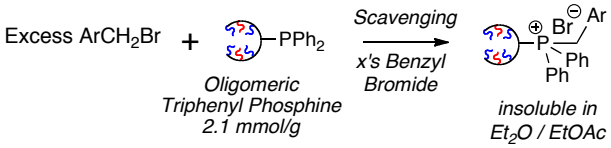


One of the more important attributes of this method is the ability to fine-tune the oligomer solubility profile via control of the oligomer length. Typically, shorter oligomers are soluble in common reaction solvents (CH_2Cl_2, $CHCl_3$, THF, DMF), yet can often be precipitated from CH_3OH, Et_2O, EtOAc or hexanes.

The synthesis of ROM polymerization derived oligomeric triphenyl phosphine (OTPP) for use in a polymer-on-polymer Mitsunobu reaction was recently reported by the Hanson group.[30] OTPP was found to be soluble in chlorinated solvents, toluene and THF, while remaining completely insoluble in CH_3OH and EtOAc. This solubility profile of oligomeric reagents is highly useful in library production as it allows for the preparation of stock solutions along with facile dispensing in high throughput synthesis.

The use of resin-supported triphenyl phosphine for the scavenging of excess alkyl halides has been reported in the literature.[31] Therefore it was envisioned that OTPP could be utilized for scavenging of benzyl bromides in solution phase, followed by the precipitation of the OTPP as well as the supported phosphorane. Subsequent filtration would then afford desired products circumventing the use of column chromatography for purification (Scheme 5.7).

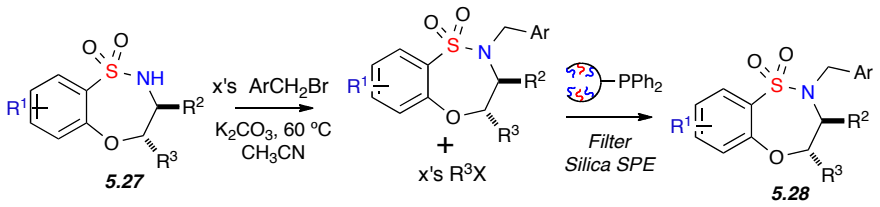
Scheme 5.7



It is our aim to incorporate ROMP-derived soluble oligomeric reagents and scavengers produced within our program in the production of libraries.[32] In the previous section we had demonstrated the ability of the benzothiaoxazepine-1,1-dioxide **5.6f** to undergo facile benzylation. The utilization of OTPP for scavenging benzyl bromides in a benzylation event of benzothiaoxazepine-1,1-dioxide was

envisioned. Therefore, we next embarked upon the production of a prototype library of benzylated benzothiaoxazepoine-1,1-dioxides. The protocol established above (Scheme 5.3) was utilized to prepare a 16 member library of benzylated benzothiaoxazepoine-1,1-dioxides. Upon completion of reaction (via TLC), a toluene solution of OTPP (3.0 equiv.) was added and the reaction mixture was stirred overnight at 80 ºC. Subsequently, excess OTPP as well as the immobilized phosphorane was precipitated out by addition of a 1:1 EtOAc: Et_2O (2 mL). Filtration through a silica SPE cartridge and evaporation of solvent afforded the desired products in excellent yields and purities (Table 5. 4). Overall, this protocol does not require any column chromatography and coupled with the differential solubility profile of OTPP, the aforementioned facilitated protocol presents an attractive platform for production of larger libraries.

Table 5.4



Entry	R^1	R^2	R^3	Ar	Yield (%)
1	4-Br	CH_3	Ph	Allyl	89
2	3-Cl	^{i}Bu	H	Allyl	86
3	3-Cl	^{i}Bu	H	3-F	83
4	4-Br	^{i}Bu	H	4-F	81
5	3-Cl	Me	Ph	4-CH_3	74
6	3-Cl	Me	Ph	2-CH_3	74
7	3-Cl	iBu	H	Me	72
8	5-Cl	iPr	H	3,4-dichloro	81
9	4-Br	iBu	H	4-F	82
10	4-Br	iBu	H	3-F	82
11	4-Br	iBu	H	3-Cl	81
12	4-Br	iBu	H	3,4-dicloro	76
13	6-F	iBu	H	4-F	75
14	6-F	iBu	H	3-F	66
15	6-F	iBu	H	3-Cl	78
16	6-F	iBu	H	3,4-dicloro	79

5.3. Summary and Future Outlook

In conclusion a "click, cyclize, click" approach to diverse benzofused sultams has been developed. This strategy utilizes the complementary pairing of α-flurobenzenesulfonyl chlorides and amino alcohols via a tandem sulfonylation – intramolecular S_NAr *O*-arylation sequence to produce an array of benzothiaoxzepine-1,1-dioxides bearing a free sulfonamide N-H. The synthetic utility of the free sulfonamide N-H was subsequently probed to reveal a number of diversification reactions including Mitsunobu alkylations, benzylation/allylation and acylations to afford an array of peripherally diverse benzothiaoxzepine-1,1-dioxides. Intermolecular S_NAr aminations were also utilized to functionalize the aromatic ring system. Additionally, a strategy outlining the utilization of intermolecular Mitsunobu alkylation pathways for accessing stereochemical diversity has been reported. Overall, an array of benzofused sultam scaffolds with a high degree of versatility for library production has been produced and a number of prototypical libraries have been prepared.

This project has much potential for the production of large libraries. Future endeavors should focus toward the utilization of the bi-functional nature of these scaffolds in library production employing continuous flow synthesis. Furthermore, the Mitsunobu alkylation route and intermolecular S_NAr routes should be harnessed fully to generate complete matrices of stereoisomers of benzothiaoxazepine-1,1-dioxides as well as other structurally diverse benzofused sultams.

5.4. References Cited

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Chapter 6

Experimental Data: Chapters 3-5

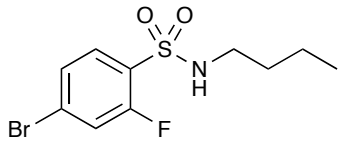
5.1. General Experimental Methods

All air and moisture sensitive reactions were carried out in flame- or oven-dried glassware under argon atmosphere using standard gastight syringes, cannulae, and septa. Stirring was achieved with oven-dried magnetic stir bars. Et_2O, toluene, THF and CH_2Cl_2 were purified by passage through the Solv-Tek purification system employing activated Al_2O_3 (Grubbs, R.H.; Rosen, R.K.; Timmers, F.J.; *Organometallics* **1996**, *15*, 1518-1520). Et_3N was purified by passage over basic alumina and stored over KOH. Microwave reactions were carried out using Biotage Initiator using 0.5-2.0 mL, 2.0-5.0 mL, and 10-20 mL Vials. Flash column chromatography was performed with Merck silica gel (EM-9385-9, 230-400 mesh) or via the Biotage SP System with FLASH 12+ or FLASH 40+ cartridges. Thin layer chromatography was performed on silica gel $60F_{254}$ plates (EM-5717, Merck). Deuterated solvents were purchased from Cambridge Isotope laboratories. ^{1}H and ^{13}C spectra were recorded on a Bruker Avance operating at 500 MHz and 125 MHz respectively, in $CDCl_3$ unless otherwise noted. High-resolution mass spectrometry (HRMS) and EI spectra were obtained on a VG Instrument ZAB double-focusing mass spectrometer.

General Procedure for preparation of α-fluorobenzene sulfonamide

To a vigorously stirred solution of amine (7.34 mmol, 2.0 equiv.) in CH_2Cl_2 (12.2 mL, 0.3 M) in a round bottom flask was added $NaHCO_3$ (3 equiv.) and H_2O (6.1 mL, 0.6 M). A solution of benzenesulfonyl chloride (1.0 g, 3.67 mmol) in CH_2Cl_2 (3.6 mL, 1 M) was added dropwise, and the reaction was stirred for 4-8 hours. Upon disappearance of sulfonyl chloride, 10% HCl (10 mL) was added and the reaction was stirred for 10 minutes. The organic layer was separated and the aqueous layer extracted with CH_2Cl_2 (3 x 5 mL). The combined organic layers were washed with brine (10 mL), dried (Na_2SO_4), concentrated under reduced pressure and subjected to column chromatography (3:1, hexane:EtOAc) to afford the *o*-fluorobenzenesulfonamide.

4-bromo-*N*-butyl-2-fluorobenzenesulfonamide



Light yellow solid, 1.10 g (97%), mp 172-174 ºC.

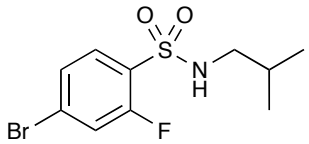
FTIR (thin film): 3261, 2923, 2850, 1577, 1560, 1448, 1369, 1326, 1164 cm^{-1}

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.77-7.73 (m, 1H), 7.44-7.37 (m, 2H), 4.91 (t, J = 5.9 Hz, 1H), 2.98 (dd, J = 13.4, 6.9 Hz, 2H), 1.49-1.41 (m, 2H), 1.29 (dq, J = 14.5, 7.3 Hz, 2H), 0.85 (t, J = 7.4 Hz, 3H);

^{13}C NMR (125 MHz, $CDCl_3$) δ 158.3 (d, $J_{C\text{-}F}$ = 258.4 Hz), 131.4, 128.1 (d, $J_{C\text{-}F}$ = 9.1 Hz, 1H), 128.0 (d, $J_{C\text{-}F}$ = 3.8 Hz), 127.3 (d, $J_{C\text{-}F}$ = 13.8 Hz), 120.5 (d, $J_{C\text{-}F}$ = 24.4 Hz), 42.9, 31.5, 19.0, 13.4;

HRMS calculated for $C_{10}H_{12}FBrNO_2S$ $(M\text{-}H)^+$ 307.9756; found 307.9737 (EI).

4-bromo-2-fluoro-*N*-isobutylbenzenesulfonamide



White Solid 1.3 g (92%), mp 149-150ºC.

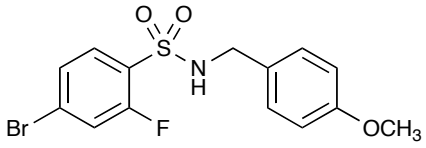
FTIR (thin film): 3298, 2960, 2873, 1589, 1569, 1469, 1396, 1334, 1164 cm^{-1}

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.78-7.74 (m, 1H), 7.45-7.39 (m, 2H), 4.78 (t, J = 6.1 Hz, 1H), 2.79 (t, J = 6.6 Hz, 2H), 1.73 (dp, J = 13.4, 6.7 Hz, 1H), 0.89 (d, J = 6.7 Hz, 6H);

^{13}C NMR (125 MHz, $CDCl_3$) δ 158.3 (d, $J_{C\text{-}F}$ = 258.2 Hz), 131.3, 128.1 (d, $J_{C\text{-}F}$ = 9.2 Hz), 127.9 (d, $J_{C\text{-}F}$ = 3.8 Hz), 127.3 (d, $J_{C\text{-}F}$ = 13.9 Hz), 120.6 (d, $J_{C\text{-}F}$ = 24.4 Hz), 50.6, 28.5, 19.7;

HRMS calculated for $C_{10}H_{12}FBrNO_2S$ $(M\text{-}H)^+$ 307.9756; found 307.9727 (EI).

4-bromo-2-fluoro-*N*-(4-methoxybenzyl)benzenesulfonamide



White Solid 1.30 g (96%), mp 107-108 ºC.

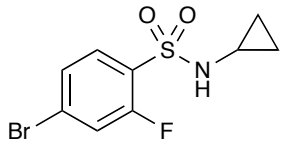
FTIR (thin film): 3270, 2931, 1589, 1492, 1357, 1348, 1321, 1251, 1226, 1164 cm^{-1}

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.71 (dd, *J* = 8.3, 7.8 Hz, 1H), 7.39 (ddd, *J* = 8.4, 1.8, 0.6 Hz, 1H), 7.31 (dd, *J* = 9.5, 1.8 Hz, 1H), 7.10-7.05 (m, 2H), 6.78-6.73 (m, 2H), 5.02 (t, *J* = 6.0 Hz, 1H), 4.13 (d, *J* = 6.1 Hz, 2H), 3.77 (s, 3H);

^{13}C NMR (125 MHz, $CDCl_3$) δ 159.4, 158.3 (d, $J_{C\text{-}F}$ = 258.2), 131.3, 129.3, 128.1 (d, $J_{C\text{-}F}$ = 9.3 Hz), 127.8 (d, $J_{C\text{-}F}$ = 3.7 Hz), 127.6, 127.5 (d, $J_{C\text{-}F}$ = 13.1 Hz), 120.5 (d, $J_{C\text{-}F}$ = 24.4 Hz), 114.0, 55.3, 47.0;

HRMS calculated for $C_{14}H_{12}FBrNO_3S$ $(M\text{-}H)^+$ 371.9705; found 371.9699 (EI).

4-bromo-*N*-cyclopropyl-2-fluorobenzenesulfonamide



White Solid 1.01 g (94%), mp 88-89 ºC.

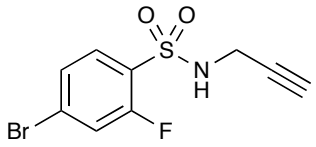
FTIR (thin film): 3286, 3093, 3020 1589, 1568, 1469, 1400, 1349, 1330, 1137 cm^{-1}

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.8 (dd, *J* = 8.3, 7.8 Hz, 1H), 7.46 (ddd, *J* = 8.4, 1.8, 0.7 Hz, 1H), 7.41 (dd, *J* = 9.4, 1.8 Hz, 1H), 5.28 (d, *J* = 14.1 Hz, 1H), 2.26 (ttd, *J* = 6.7, 3.5, 1.3 Hz, 1H), 0.68-0.63 (m, 2H), 0.60 (tdd, *J* = 7.6, 5.9, 1.6 Hz, 2H);

^{13}C NMR (125 MHz, $CDCl_3$) δ 158.4 (d, $^{1}J_{C\text{-}F}$ = 259.2 Hz), 131.8, 128.5 (d, $J_{C\text{-}F}$ = 9.2 Hz), 128.0 (d, $J_{C\text{-}F}$ = 3.8 Hz), 126.8 (d, $J_{C\text{-}F}$ = 13.7 Hz), 120.6 (d, $J_{C\text{-}F}$ = 24.4 Hz), 24.2, 6.1;

HRMS calculated for $C_9H_9FNO_2SNa$ $(M\text{-}H)^+$ 291.9443; found 291.9436 (EI).

4-bromo-2-fluoro-*N*-(prop-2-ynyl)benzenesulfonamide



White Solid 1.02g (88%), mp 104-105 ºC.

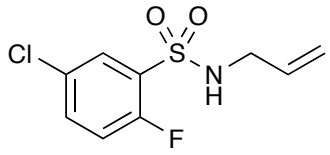
FTIR (thin film): 3248, 2128, 1598, 1571, 1460, 1400, 1361, 1332, 1161 cm^{-1}

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.80-7.77 (m, 1H), 7.45 (ddd, *J* = 8.3, 1.8, 0.6, 1H), 7.42 (dd, J= 9.4, 1.8, 1H), 4.99 (t, *J* = 5.9, 1H), 3.93 (dd, *J* = 6.2, 2.5, 2H), 2.06 (t, *J* = 2.5, 1H);

^{13}C NMR (125 MHz, $CDCl_3$) δ 158.7 (d, $J_{C\text{-}F}$ = 258.6 Hz), 131.2, 128.61 (d, $J_{C\text{-}F}$ = 9.3 Hz), 127.9 (d, $J_{C\text{-}F}$ = 3.7 Hz), 127.2 (d, $J_{C\text{-}F}$ = 13.8 Hz), 120.5 (d, $J_{C\text{-}F}$ = 24.3 Hz), 77.1, 73.1, 32.9;

HRMS calculated for $C_9H_6FNO_2S$ $(M\text{-}H)^+$ 289.9287; found 289.9281 (EI).

***N*-allyl-5-chloro-2-fluorobenzenesulfonamide**



White Solid 0.82 g (89 %), mp 81-82 ºC.

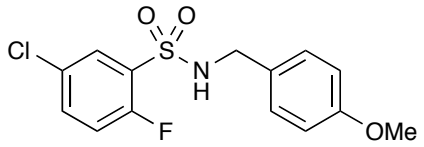
FTIR (thin film): 3292, 3095, 3076, 1649, 1596, 1467, 1429, 1334, 1255, 1164 cm^{-1}

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.88 (dd, *J* = 6.1, 2.7 Hz, 1H), 7.53 (ddd, *J* = 8.8, 4.3, 2.7 Hz, 1H), 7.17 (t, *J* = 9.1 Hz, 1H), 5.73 (ddt, *J* = 16.1, 10.3, 5.9 Hz, 1H), 5.20 (ddd, *J* = 17.1, 2.6, 1.5 Hz, 1H), 5.13 (dd, *J* = 10.2. 1.2 Hz, 1H), 4.81 (s, 1H), 3.69 (t, *J* = 6.0 Hz, 2H);

^{13}C NMR (125 MHz, $CDCl_3$) δ 157.2 (d, $J_{C\text{-}F}$ = 254.0 Hz), 134.7 (d, $J_{C\text{-}F}$ = 8.6 Hz), 132.4, 130.0, 129.9 (d, $J_{C\text{-}F}$ = 3.6 Hz), 129.7 (d, $J_{C\text{-}F}$ = 15.4 Hz), 118.3 (d, $J_{C\text{-}F}$ = 23.3 Hz), 118.2, 45.8;

HRMS calculated for $C_9H_8ClFNO_2S$ $(M\text{-}H)^+$ 247.9948; found 247.9941 (EI).

5-chloro-2-fluoro-*N*-(4-methoxybenzyl)benzenesulfonamide



White Solid 1.05 g (87%), mp 41-42 ºC.

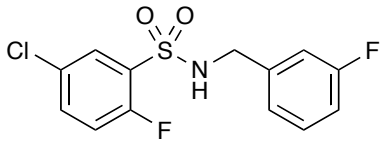
FTIR (thin film): 3299, 3097, 1616, 1593, 1471, 1467, 1388, 1338, 1166 cm^{-1}

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.75 (dd, *J* = 2.7, 6.1 Hz, 1H), 7.45 (ddd, *J* = 2.7, 4.2, 8.8 Hz, 1H), 7.11-7.05 (m, 3H), 6.76-6.71 (m, 2H), 5.23 (t, *J* = 6.0 Hz, 1H), 4.15 (d, *J* = 6.1 Hz, 2H), 3.75 (s, 3H);

^{13}C NMR (125 MHz, $CDCl_3$) δ 159.2, 157.0 (d, $J_{C\text{-}F}$ = 254.0 Hz), 134.3 (d, $J_{C\text{-}F}$ = 8.6 Hz), 129.8, 129.7 (d, $J_{C\text{-}F}$ = 12.5 Hz), 129.6, 129.3, 127.4, 118. 1 (d, $J_{C\text{-}F}$ = 23.2 Hz), 113.9, 55.2, 46.9;

HRMS calculated for $C_{14}H_{12}ClFNO_3S$ $(M\text{-}H)^+$ 328.0210; found 328.0220 (EI).

5-chloro-2-fluoro-*N*-(3-fluorobenzyl)benzenesulfonamide



White Solid 0.96 g (81%), mp 81-82 ºC.

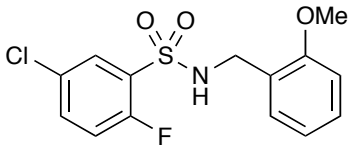
FTIR (thin film): 3298, 2941, 2358, 1602, 1494, 1467, 1340, 1310, 1166 cm^{-1}

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.81 (dd, *J* = 6.1, 2.7 Hz, 1H), 7.51-7.46 (m, 1H), 7.25-7.21 (m, 1H), 7.13-7.09 (m, 1H), 6.99 (dd, *J* = 11.5, 3.9 Hz, 1H), 6.95-6.89 (m, 2H), 5.23 (t, *J* = 6.1 Hz, 1H), 4.23 (d, *J* = 6.3 Hz, 2H);

^{13}C NMR (125 MHz, $CDCl_3$) δ 162.71 (d, $J_{C\text{-}F}$ = 247.1 Hz), 157.02 (d, $J_{C\text{-}F}$ = 254.1 Hz), 138.1 (d, $J_{C\text{-}F}$ = 7.2 Hz), 134.65 (d, $J_{C\text{-}F}$ = 8.6 Hz), 130.20 (d, $J_{C\text{-}F}$ = 8.2 Hz), 129.8, 129.8, 129.5 (d, $J_{C\text{-}F}$ = 15.4 Hz), 123.4 (d, $J_{C\text{-}F}$ = 3.0 Hz), 118.24 (d, $J_{C\text{-}F}$ = 23.1 Hz) 46.7 (d, $J_{C\text{-}F}$ = 1.5 Hz).

HRMS calculated for $C_{13}H_9ClF_2NO_2S$ $(M\text{-}H)^+$ 316.0011; found 316.0013 (EI).

5-chloro-2-fluoro-*N*-(2-methoxybenzyl)benzenesulfonamide



White Solid 1.10 g (90%), mp 99-101 ºC.

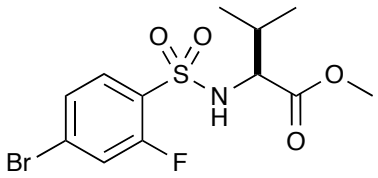
FTIR (thin film): 3298, 2941, 2358, 1602, 1494, 1467, 1340, 1310, 1166 cm^{-1}

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.64 (dd, *J* = 6.1, 2.7 Hz, 1H), 7.31 (ddd, *J* = 8.8, 4.3, 2.7 Hz, 1H), 7.12 (td, *J* = 8.1, 1.7 Hz, 1H), 6.92 (dd, *J* = 7.4, 1.6 Hz, 1H), 6.87-6.82 (m, 1H), 6.71 (td, *J* = 7.4, 0.9 Hz, 1H), 6.67 (d, *J* = 8.2 Hz, 1H), 5.59 (t, *J* = 6.3 Hz, 1H), 4.25 (d, *J* = 6.5 Hz, 2H), 3.78 (s, 3H);

^{13}C NMR (125 MHz, $CDCl_3$) δ 157.1, 157.0 (d, $J_{C\text{-}F}$ = 252.7 Hz), 134.0 (d, $J_{C\text{-}F}$ Hz, = 8.6), 130.0, 129.9 (d, $J_{C\text{-}F}$ = 15.7 Hz), 129.7, 129.5, 129.4 (d, $J_{C\text{-}F}$ = 3.6 Hz), 122.9, 120.2, 117.6 (d, *J* = 23.3 Hz), 109.8, 55.0, 44.6.

HRMS calculated for $C_{14}H_{12}ClFNO_3S$ $(M\text{-}H)^+$ 328.0210; found 328.0217 (EI).

(*S*)-methyl 2-(4-bromo-2-fluorophenylsulfonamido)-3-methylbutanoate



White Solid 1.24 g (92 %), mp 71-72 ºC.

$[\alpha]_D^{20}$ + 53.8 (*c* = 0.52, $CHCl_3$)

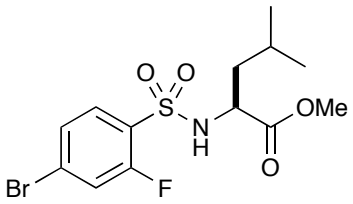
FTIR (thin film): 3288, 2968, 1739, 1589, 1569, 1471, 1398, 1350, 1172 cm^{-1}

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.73-7.68 (m, 1H), 7.41-7.37 (m, 2H), 5.39 (d, *J* = 9.9 Hz, 1H), 3.87 (dd, *J* = 5.0, 9.9 Hz, 1H), 3.53 (s, 3H), 2.15-2.05 (m, 1H), 0.97 (d, *J* = 6.8 Hz, 3H), 0.88 (d, *J* = 6.9 Hz, 3H);

^{13}C NMR (125 MHz, $CDCl_3$) δ δ 171.4 (s, 1H), 158.6 (d, $J_{C\text{-}F}$ = 259.8, Hz), 130.9, 128.4 (d, $J_{C\text{-}F}$ = 9.2 Hz), 127.7(d, $J_{C\text{-}F}$ = 3.8 Hz), 127.2 (d, $J_{C\text{-}F}$ = 14.1 Hz), 120.5 ($J_{C\text{-}F}$ = 24.4 Hz), 61.3, 52.3, 31.4, 18.9, 17.3;

HRMS calculated for $C_{12}H_{14}FBrNO_4S$ $(M\text{-}H)^+$ 365.9811; found 365.9800 (EI).

(*S*)-methyl 2-(4-bromo-2-fluorophenylsulfonamido)-4-methylpentanoate



White Solid 1.31g (94%), mp 82-83 ºC.

FTIR (thin film): 3282, 3093, 2956, 1743, 1589, 1569, 1471, 1398, 1350, 1170 cm^{-1}

$[\alpha]_D^{20}$ + 35.0 (*c* = 0.60, $CHCl_3$)

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.73-7.69 (m, 1H), 7.40 (ddd, *J* = 9.6, 5.3, 1.1 Hz, 2H), 5.32 (d, *J* = 9.9 Hz, 1H), 4.06 (dt, *J* = 9.7, 7.4 Hz, 1H), 3.51 (s, 3H), 1.85-1.74 (m, 1H), 1.54 (t, *J* = 7.2 Hz, 2H), 0.91 (dd, *J* = 6.6, 4.0 Hz, 6H);

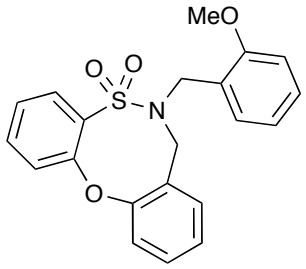
^{13}C NMR (125 MHz, $CDCl_3$) δ 172.3, 158.7 ($J_{C\text{-}F}$ = 259.6 Hz), 130.9, 128.4 ($J_{C\text{-}F}$, *J* = 9.2 Hz), 127.7 ($J_{C\text{-}F}$, *J* = 3.8 Hz), 127.2 ($J_{C\text{-}F}$, *J* = 14.1 Hz), 120.5 (d, *J* = 24.3 Hz), 54.6, 52.4, 42.1, 24.3, 22.7, 21.3;

HRMS calculated for $C_{13}H_{14}FBrNO_4S$ $(M\text{-}H)^+$ 379.9967; found 379.9959 (EI).

General procedure for [4+4] reaction

A flame-dried vial was charged with the sulfonamide (0.090 g, 0.29 mmol), *o*-silyloxy benzyl acetate (0.165 g, 0.584 mmol), THF (0.5 M, 0.58 mL) and TBAF (0.88 mmol, 0.88 mL). The vial was quickly sealed and stirred for 30 minutes under *mW* irradiation at 100 ºC. Upon completion of the reaction, the mixture was concentrated under reduced pressure and subjected to column chromatography (6:1 hexane:EtOAc) to afford the product as a white solid.

6-(2-methoxybenzyl)-6,7-dihydrodibenzo[b,g][1,4,5]oxathiazocine 5,5-dioxide



White solid, 92 mg (71%), mp 173-174 ºC.

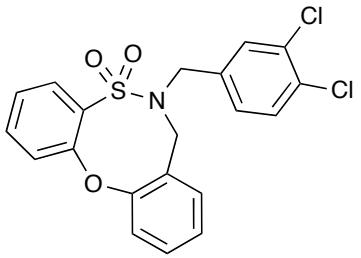
FTIR (thin film): 3064, 2926, 2358, 2341, 1610, 1581, 1478, 1452, 1353, 1340 cm^{-1}

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.98 (dd, *J* = 7.8, 1.7 Hz, 1H), 7.62 (tdd, *J* = 9.1, 8.2, 1.4 Hz, 3H), 7.55 (d, *J* = 7.6 Hz, 1H), 7.39 (td,*s*= 7.8, 1.7 Hz, 1H), 7.29 (td, *J* = 7.6, 1.1 Hz, 2H), 7.13 (td, *J* = 7.4, 1.0 Hz, 1H), 7.04 (td, *J* = 7.5, 0.9 Hz, 1H), 6.99 (dd, *J* = 7.4, 1.7 Hz, 1H), 6.84 (d, *J* = 7.6 Hz, 1H), 5.57 (dd, *J* = 15.2, 1.3 Hz, 1H), 4.10 (d, *J* = 16.0 Hz, 1H), 3.81 (d, *J* = 15.2 Hz, 1H), 3.73 (d, *J* = 16.0 Hz, 1H), 3.68 (s, 3H);

^{13}C NMR (125 MHz, $CDCl_3$) δ 159.3, 157.1, 155.5, 134.4, 134.3, 131.7, 130.4, 130.3, 130.2, 129.2, 128.8, 125.2, 124.1, 123.6, 122.2, 120.8, 110.1, 55.0, 47.6, 42.8;

HRMS calculated for $C_{21}H_{19}BrNO_4S$ $(M+Na)^+$ 404.0933; found 404.0927 (EI).

6-(3,4-dichlorobenzyl)-6,7-dihydrodibenzo[b,g][1,4,5]oxathiazocine 5,5-dioxide



White solid, 91mg, (73%), mp 134-136 ºC.

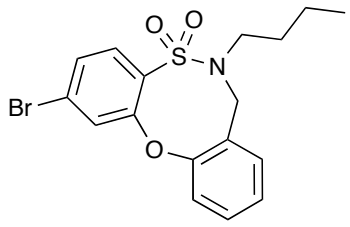
FTIR (thin film): 3071, 2358, 2341, 1577, 1488, 1460, 1400, 1338, 1164 cm^{-1}

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.95 (dd, *J* = 7.8, 1.6 Hz, 1H), 7.63 (dtd, *J* = 9.9, 8.2, 1.4 Hz, 2H), 7.57 (d, *J* = 7.6 Hz, 1H), 7.42 (dd, *J* = 11.8, 5.0 Hz, 2H), 7.39 (d, *J* = 1.5 Hz, 1H), 7.30 (td, *J* = 7.7, 1.3 Hz, 1H), 7.20 (dd, *J* = 7.4, 1.0 Hz, 1H), 7.18-7.14 (m, 1H), 7.00 (dd, *J* = 7.4, 1.6 Hz, 1H), 5.56 (dd, *J* = 15.3, 1.2 Hz, 1H), 4.35 (d, *J* = 15.2 Hz, 1H), 3.68 (d, *J* = 15.3 Hz, 1H), 3.19 (d, *J* = 15.2 Hz, 1H);

^{13}C NMR (125 MHz, $CDCl_3$) δ 159.2, 155.3, 135.7, 134.7, 133.9, 132.9, 132.1, 131.3, 130.7, 130.6, 130.4, 130.1, 129.5, 127.6, 125.6, 125.4, 124.1, 122.5, 47.6, 47.2;

HRMS calculated for $C_{12}H_{14}FBrNO_4S$ $(M-H)^+$ 365.9811; found 365.9800 (EI).

2-bromo-6-butyl-6,7-dihydrodibenzo[b,g][1,4,5]oxathiazocine 5,5-dioxide



White solid, 103 mg (90%), mp 171-172 ºC.

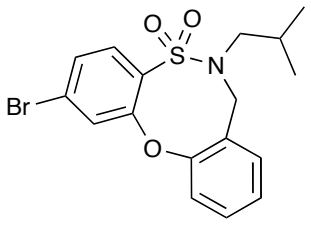
FTIR (thin film): 3261, 2923, 2850, 2356, 2339, 1470, 1396, 1332, 1164 cm^{-1}

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.79 (d, *J* = 8.4 Hz, 1H), 7.76 (d, *J* = 1.8 Hz, 1H), 7.50 (d, *J* = 7.8 Hz, 1H), 7.42 (dq, *J* = 5.1, 2.0 Hz, 2H), 7.24-7.18 (m, 2H), 5.55 (d, *J* = 15.3 Hz, 1H), 3.96 (t, *J* = 17.7 Hz, 1H), 3.00-2.92 (m, 1H), 2.28-2.22 (m, 1H), 1.64-1.48 (m, 3H), 1.39-1.31 (m, 1H), 1.29-1.19 (m, 1H), 0.89 (t, *J* = 7.4 Hz, 3H);

^{13}C NMR (125 MHz, $CDCl_3$) δ 158.8, 155.6, 133.4, 131.5, 131.3, 130.5, 130.1, 128.5, 127.6, 127.5, 125.9, 122.2, 47.3, 44.5, 29.5, 19.6, 13.7;

HRMS calculated for $C_{16}H_{14}BrNNaO_3S$ (M+Na) 401.9775; found 401.9773 (EI).

2-bromo-6-isobutyl-6,7-dihydrodibenzo[b,g][1,4,5]oxathiazocine 5,5-dioxide



White Solid, 104 mg (91%), mp 125-126 ºC.

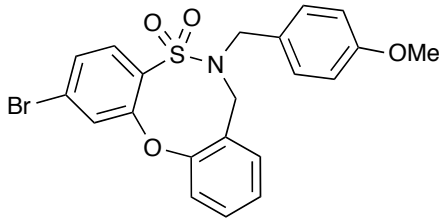
FTIR (thin film): 3061, 2923, 2850, 2356, 2339, 1470, 1396, 1332, 1164 cm^{-1}

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.77 (dd, *J* = 11.3, 5.1 Hz, 2H), 7.50 (d, *J* = 8.1 Hz, 1H), 7.44-7.40 (m, 2H), 7.22-7.18 (m, 2H), 5.59 (dd, *J* = 15.3, 1.2 Hz, 1H), 3.92 (d, *J* = 15.3 Hz, 1H), 2.66-2.59 (m, 1H), 2.09-2.04 (m, 1H), 2.04-1.97 (m, 1H), 0.98 (d, *J* = 6.6, 3H), 0.82 (d, *J* = 6.5 Hz, 3H);

^{13}C NMR (125 MHz, $CDCl_3$) δ 158.8, 155.6, 133.2, 131.6, 131.4, 130.5, 129.7, 128.5, 127.7, 127.5, 125.9, 122.2, 51.7, 47.6, 26.0, 20.2, 19.5;

HRMS calculated for $C_{16}H_{14}BrNNaO_3S$ (M+Na) 401.9775; found 401.9772 (EI).

2-bromo-6-(4-methoxybenzyl)-6,7-dihydrodibenzo[b,g][1,4,5]oxathiazocine 5,5-dioxide



Colorless oil, 101 mg (82%).

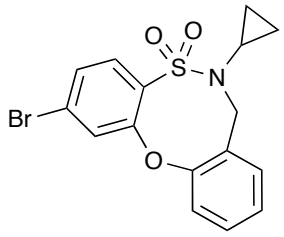
FTIR (thin film): 3087, 2997, 2931, 2442, 2393, 1569, 1400, 1388, 1338, 1161 cm^{-1}

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.83 (d, *J* = 8.4 Hz, 1H), 7.80 (d, *J* = 1.8 Hz, 1H), 7.53 (d, *J* = 8.0 Hz, 1H), 7.44 (ddd, *J* = 7.2, 4.4, 1.6 Hz, 2H), 7.24-7.18 (m, 3H), 7.02 (dd, *J* = 7.4, 1.6 Hz, 1H), 6.93-6.88 (m, 2H), 5.45 (d, *J* = 15.2 Hz, 1H), 4.39 (d, *J* = 14.5 Hz, 1H), 3.83 (s, 3H), 3.70 (d, *J* = 15.3 Hz, 1H), 3.12 (d Hz, *J* = 14.5, 1H);

^{13}C NMR (125 MHz, $CDCl_3$) δ 159.4, 159.0, 155.7, 133.5, 131.7, 131.3, 130.6, 129.9, 129.7, 128.6, 127.8, 127.5, 126.7, 125.8, 122.3, 114.08, 77.25, 55.3, 48.0, 46.6;

HRMS calculated for $C_{21}H_{18}BrNO_4SNa$ $(M+Na)^+$ 482.0038; found 482.0050 (EI).

2-bromo-6-cyclopropyl-6,7-dihydrodibenzo[b,g][1,4,5]oxathiazocine 5,5-dioxide



White Solid, 104 mg (81%), mp 175-176 ºC.

X-Ray page *S-39*

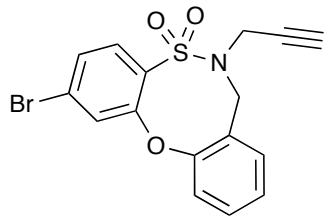
FTIR (thin film): 3280, 3071, 3020, 2350, 2335, 1400, 1359, 1330 cm^{-1}

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.92 (dd, *J* = 7.8, 1.6 Hz, 1H), 7.58-7.51 (m, 2H), 7.45 (d, *J* = 7.6 Hz, 1H), 7.31 (td, *J* = 7.7, 1.6 Hz, 1H), 7.26-7.20 (m, 2H), 7.10 (td, *J* = 7.4, 1.1 Hz, 1H), 5.52 (d, *J* = 14.8 Hz, 1H), 3.87 (d, *J* = 14.8 Hz, 1H), 1.28-1.22 (m, 2H), 0.63-0.56 (m, 2H), 0.41-0.33 (m, 1H);

^{13}C NMR (125 MHz, $CDCl_3$) δ 159.1, 155.4, 134.6, 133.1, 131.7, 131.3, 130.2, 130.1, 125.6, 125.3, 124.1, 122.1, 50.9, 27.7, 10.2, 5.2;

HRMS calculated for $C_{17}H_{18}BrNNaO_3$ (M+Na) 418.0088; found 418.0083(EI).

2-bromo-6-(prop-2-yn-1-yl)-6,7-dihydrodibenzo[*b*,*g*][1,4,5]oxathiazocine 5,5-dioxide



White Solid, 118 mg (94%), mp 140-141 ºC.

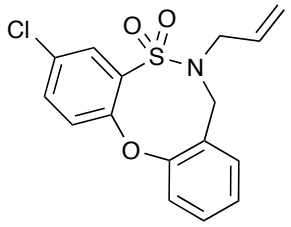
FTIR (thin film): 3092, 2354, 2334, 2123, 1569, 1452, 1390, 1352, 1344, 1164 cm^{-1}

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.78 (dd, *J* = 5.1, 6.9 Hz, 2H), 7.48 (d, *J* = 7.0 Hz, 1H), 7.44 (ddt, *J* = 2.1, 4.2, 8.3 Hz, 2H), 7.36 (dd, *J* = 1.6, 7.4 Hz, 1H), 7.23 (td, *J* = 1.2, 7.4 Hz, 1H), 5.60 (d, *J* = 15.4 Hz, 1H), 4.20 (d, *J* = 15.3 Hz, 1H), 3.98 (ddd, *J* = 1.3, 2.5, 17.3 Hz, 1H), 3.26 (dd, *J* = 2.5, 17.3 Hz, 1H), 2.15 (t, *J* = 2. Hz, 5, 1H);

^{13}C NMR (125 MHz, $CDCl_3$) δ 158.9, 155.6, 133.1, 131.6, 131.3, 130.8, 129.3, 128.7, 128.1, 127.6, 126.0, 121.8, 76.2, 73.9, 48.1, 35.8;

HRMS calculated for $C_{16}H_{12}BrNNaO_3S$ (M+Na) 399.9619; found 339.9618 (EI).

6-allyl-3-chloro-6,7-dihydrodibenzo[b,g][1,4,5]oxathiazocine 5,5-dioxide



White Solid, 87 mg (95%), mp 138-140 ºC.

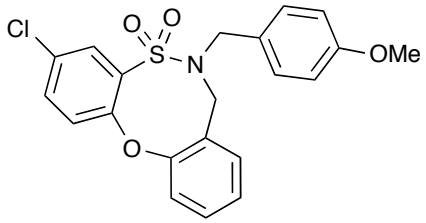
FTIR (thin film): 3082, 2974, 2358, 2341, 1604, 1577, 1452, 1386, 1342, 1164 cm^{-1}

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.90 (d, *J* = 2.5 Hz, 1H), 7.56 (d, *J* = 8.6 Hz, 1H), 7.52 (dd, *J* = 8.7, 2.5 Hz, 1H), 7.48 (d, *J* = 8.2 Hz, 1H), 7.39 (dt, *J* = 8.1, 3.7 Hz, 1H), 7.18 (dd, *J* = 5.0, 0.8 Hz, 2H), 5.74 (dddd, *J* = 17.1, 10.1, 8.5, 3.8 Hz, 1H), 5.52 (dd, *J* = 15.2, 1.5 Hz, 1H), 5.26 (d, *J* = 10.1 Hz, 1H), 5.18 (ddt, *J* = 17.1, 2.1, 1.1 Hz, 1H), 3.95 (d, *J* = 15.2 Hz, 1H), 3.81 (ddq, *J* = 15.3, 3.7, 1.8 Hz, 1H), 2.83 (dd, *J* = 15.2, 8.5 Hz, 1H);

^{13}C NMR (125 MHz, $CDCl_3$) δ 159.0, 153.8, 135.7, 134.1, 132.2, 131.5, 130.8, 130.5, 130.1, 129.9, 125.7, 125.4, 122.2, 119.3, 47.8, 47.1.

HRMS calculated for $C_{16}H_{15}ClNO_3S$ $(M+H)^+$ 336.0461; found 336.0468 (EI).

3-chloro-6-(4-methoxybenzyl)-6,7-dihydrodibenzo[b,g][1,4,5]oxathiazocine-5,5-dioxide



White Solid, 92 mg (87%), mp 138-139 ºC.

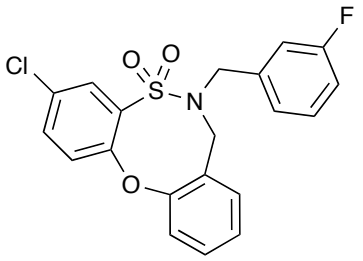
FTIR (thin film): 3072, 2933, 2835, 2358, 2331, 1610, 1512, 1358, 1338, 1164 cm^{-1}

^{1}H **NMR** (500 MHz, $CDCl_3$) δ 7.94 (d, *J* = 2.5 Hz, 1H), 7.58 (d, *J* = 8.7 Hz, 1H), 7.55-7.48 (m, 2H), 7.41 (td, *J* = 7.9, 1.7 Hz, 1H), 7.24-7.17 (m, 3H), 7.03 (dd, *J* = 7.4, 1.6 Hz, 1H), 6.92-6.87 (m, 2H), 5.45 (d, *J* = 16.1 Hz, 1H), 4.42 (d, *J* = 14.5 Hz, 1H), 3.83 (s, 3H), 3.70 (t, *J* = 10.2 Hz, 1H), 3.17 (d, *J* = 14.5 Hz, 1H);

^{13}C NMR (125 MHz, $CDCl_3$) δ 159.4, 159.0 153.8, 135.8, 134.1, 131.6, 130.8, 130.5, 130.1, 129.9, 129.8, 126.6, 125.7, 125.4, 122.2, 114.1, 55.3, 48.1, 46.6;

HRMS calculated for $C_{21}H_{18}ClNO_4SNa$ $(M+Na)^+$ 438.0543; found 438.0540 (EI).

3-chloro-6-(3-fluorobenzyl)-6,7-dihydrodibenzo[b,g][1,4,5]oxathiazocine 5,5-dioxide



White Solid, 118 mg (87%), mp 158-160 ºC.

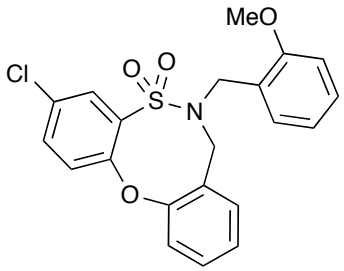
FTIR (thin film): 3078, 2929, 1591, 1487, 1452, 1353, 1340, 133, 1163 cm^{-1}

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.94 (d, *J* = 2.5 Hz, 1H), 7.61-7.58 (m, 1H), 7.55 (dd, *J* = 8.7, 2.5 Hz, 1H), 7.51 (t, *J* = 6.6 Hz, 1H), 7.44-7.40 (m, 1H), 7.35 (dd, *J* = 13.7, 7.7 Hz, 1H), 7.20 (td, *J* = 7.4, 1.0 Hz, 1H), 7.09 (d, *J* = 7.6 Hz, 1H), 7.07-7.00 (m, 3H), 5.56-5.47 (m, 1H), 4.43 (d, *J* = 15.0 Hz, 1H), 3.71 (d, *J* = 15.3 Hz, 1H), 3.24 (d, *J* = 15.0 Hz, 1H);

^{13}C NMR (125 MHz, $CDCl_3$) δ 164.0, 162.1, 159.0, 153.9, 137.6, 137.6, 135.6, 134.3, 131.5, 130.9, 130.7, 130.4, 130.3, 130.1, 130.0, 129.5, 125.8, 125.4, 123.9, 123.8, 122.3, 115.3, 115.2, 115.1, 115.0, 48.2, 48.1, 47.0.

HRMS calculated for $C_{20}H_{15}ClFNO_3SNa$ $(M+Na)^+$ 426.0343; found 426.0340 (EI).

3-chloro-6-(2-methoxybenzyl)-6,7-dihydrodibenzo[b,g][1,4,5]oxathiazocine-5,5-dioxide



White Solid, 73 mg (91%), mp 170-171 ºC.

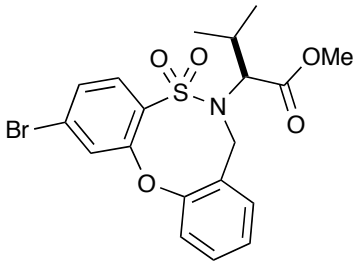
FTIR (thin film): 3072, 2939, 2356, 2339, 1464, 1386, 1330, 1164 cm^{-1}

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.95 (d, *J* = 2.5 Hz, 1H), 7.59 (d, *J* = 8.6 Hz, 2H), 7.54 (dd, *J* = 2.6, 8.7 Hz, 1H), 7.49 (d, *J* = 7.4 Hz, 1H), 7.39 (td, *J* = 1.7, 7.8 Hz, 1H), 7.30 (tt, *J* = 3.2, 6.4 Hz, 1H), 7.16-7.11 (m, 1H), 7.04 (td, *J* = 0.9, 7.5 Hz, 1H), 7.00 (dd, *J* = 1.6, 7.5 Hz, 1H), 6.84 (d, *J* = 7.6 Hz, 1H), 5.53 (dd, *J* = 1.3, 15.2 Hz, 1H), 4.15-4.08 (m, 1H), 3.79 (dd, *J* = 15.5, 32.4 Hz, 2H), 3.69 (s, 3H);

^{13}C NMR (125 MHz, $CDCl_3$) δ 159.1, 157.1, 154.0, 136.0, 134.0, 131.9, 130.7, 130.4, 130.2, 130.1, 129.3, 128.9, 125.4, 125.4, 123.3, 122.1, 120.9, 110.2, 55.0, 47.6, 43.0;

HRMS calculated for $C_{21}H_{18}ClNO_4SNa$ $(M+Na)^+$ 438.0543; found 438.0545(EI).

(S)-methyl 2-(2-bromo-5,5-dioxidodibenzo[b,g][1,4,5]oxathiazocin-6(7H)-yl)-3-methylbutanoate



White Solid, 108 mg (94%) mp 165-166 ºC.

X-Ray page *S-40*

FTIR (thin film): 2954, 2360, 2330, 1741, 1569, 1488, 1452, 1388, 1342, 1166 cm^{-1}

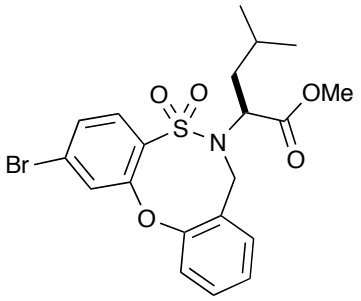
$[\alpha]_D^{20}$ **+** 5.75 (*c* = 1.49, $CHCl_3$)

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.77 (dd, *J* = 7.1, 5.1 Hz, 2H), 7.48-7.43 (m, 2H), 7.36 (dd, *J* = 8.4, 4.9 Hz, 1H), 7.16 (d, *J* = 4.3 Hz, 2H), 5.58 (d, *J* = 15.9 Hz, 1H), 3.96 (d, *J* = 10.9 Hz, 1H), 3.85 (d, *J* = 15.9 Hz, 1H), 2.46 (qd, *J* = 13.1, 6.6 Hz, 1H), 2.28 (s, 3H), 1.12 (d, *J* = 6.8 Hz, 3H), 0.98 (d, *J* = 6.3 Hz, 3H);

^{13}C NMR (125 MHz, $CDCl_3$) δ 169.2, 158.9, 155.4, 135.4, 132.3, 130.4, 130.3, 129.8, 128.2, 126.9, 126.4, 125.4, 121.7, 63.2, 50.7, 45.0, 25.5, 20.2, 18.7.

HRMS calculated for $C_{19}H_{20}BrNO_5SNa$ $(M+Na)^+$ 476.0143; found 476.0133 (EI).

(S)-methyl 2-(2-bromo-5,5-dioxidodibenzo[b,g][1,4,5]oxathiazocin-6(7H)-yl)-4-methylpentanoate



White Solid, 108 mg (77%), mp 160-161 ºC.

FTIR (thin film): 2960, 2354, 2334, 1745, 1569, 1470, 1356, 1334, 1166 cm^{-1}

$[\alpha]_D^{20}$ -4.12 (*c* = 3.01, $CHCl_3$)

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.79-7.75 (m, 2H), 7.48 (d, *J* = 8.1Hz, 1H), 7.43 (dd, *J* = 8.4, 1.8 Hz, 1H), 7.39-7.34 (m, 1H), 7.14 (d, *J* = 4.3 Hz, 2H), 5.59 (d, *J* = 15.8, 1H), 4.52 (dd, *J* = 9.9, 5.5 Hz, 1H), 3.93 (d, *J* = 15.8 Hz, 1H), 2.40 (s, 3H), 1.88 (ddd, *J* = 14.4, 10.0, 4.5 Hz, 1H), 1.77 (ddd, *J* = 14.5, 9.2, 5.5 Hz, 1H), 1.72-1.63 (m, 1H), 0.99 (dd, *J* = 13.3, 6.5 Hz, 6H);

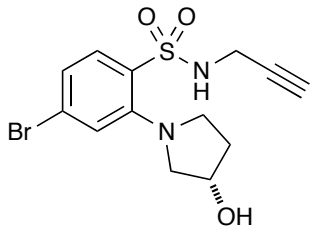
^{13}C NMR (125 MHz, $CDCl_3$) δ 170.60, 158.9, 155.2, 135.9, 131.2, 130.4, 130.1, 128.3, 126.8, 126.8, 125.6, 121.5, 56.0, 51.0, 44.4, 36.4, 23.9, 23.2, 21.3;

HRMS calculated for $C_{20}H_{22}BrNO_5SNa$ $(M+Na)^+$ 490.0300; found 490.0300 (EI).

Representative Procedure for S_NAr Addition of Amino Alcohols

To a flame dried microwave vial under Ar was added 4-bromo-2-fluoro-*N*-(prop-2-ynyl)benzenesulfonamide (202mg, 0.69 mmol), (*R*)-3-hydroxy pyrrolidine (181mg, 2.074 mmol) and DMSO (0.35 mL) was added and the reaction was heated at 150 ºC for 30 minutes in the microwave. The reaction mixture was transferred to a separatory funnel along with Et_2O (3 ml), EtOAc (1 ml) and H_2O (2 ml) and extracted. The aqeous layer was extracted with Et_2O (1 ml X 4), and the combined organic layers were dried over anhydrous Na_2SO_4. The extract was concentrated under reduced pressure and subject to column chromatography (6:1 hexane:EtOAc) to afford (R)-4-bromo-2-(3-hydroxypyrrolidin-1-yl)-N-(prop-2-yn-1-yl)benzenesulfonamide (223 mg, 91%) as a clear oil.

(R)-4-bromo-2-(3-hydroxypyrrolidin-1-yl)-N-(prop-2-yn-1-yl)benzenesulfonamide



Clear oil (121 mg, 91%)

FTIR (thin Film): 3502, 3298, 2950, 2123, 1577, 1396, 1325, 1161 cm^{-1}

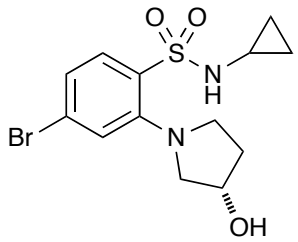
$[\alpha]_D^{20}$ -4.55 (*c* = 0.9, $CHCl_3$)

1H NMR (500 MHz, CDCl3) δ 7.84 (d, *J* = 8.5 Hz, 1H), 7.47 (d, *J* = 1.9 Hz, 1H), 7.39 (dd, *J* = 8.4, 1.9 Hz, 1H), 7.01 (t, *J* = 6.1 Hz, 1H), 4.59 (s, 1H), 3.76 (qdd, *J* = 17.9, 6.2, 2.5 Hz, 2H), 3.63 – 3.57 (m, 1H), 3.55 (d, *J* = 10.3 Hz, 1H), 3.03 (dd, *J* = 10.3, 3.5 Hz, 1H), 2.98 (td, *J* = 9.2, 6.7 Hz, 1H), 2.42 (s, 1H), 2.31 (dddd, *J* = 13.8, 9.4, 6.1, 4.4 Hz, 1H), 2.05 – 1.95 (m, 1H**).**

^{13}C NMR (125 MHz**, CDCl3) δ** 148.9, 135.8, 131.0, 128.0, 127.7, 127.1, 78.1, 72.4, 71.1, 62.1, 51.7, 34.3, 32.9.

HRMS: Calculated for $C_{13}H_{14}BrN_2O_3S$ $(M-H)^+$ 356.9909; Found 356.9900 (EI).

(*S*)-4-bromo-*N*-cyclopropyl-2-(3-hydroxypyrrolidin-1-yl)benzenesulfonamide



Clear oil (111 mg, 82%)

FTIR (thin Film): 3498, 3300, 2980, 1603, 1358, 1164 cm^{-1}

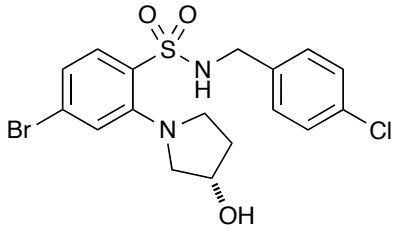
$[\alpha]_D^{20}$ = +1.44 (*c* = 2.0, $CHCl_3$)

1H NMR (500 MHz, CDCl3) 7.90 (d, *J* = 8.5 Hz, 1H), 7.47 (d, *J* = 1.9 Hz, 1H), 7.39 (dd, *J* = 8.5, 1.9 Hz, 1H), 6.86 – 6.77 (m, 1H), 4.56 (s, 1H), 3.56 – 3.49 (m, 2H), 3.05 – 2.98 (m, 2H), 2.50 – 2.41 (m, 1H), 2.30 (dddd, *J* = 13.8, 9.3, 6.0, 4.5 Hz, 1H), 2.06 (ttd, *J* = 6.9, 3.5, 2.3 Hz, 1H), 2.01 – 1.94 (m, 1H), 0.61 – 0.57 (m, 2H), 0.52 – 0.47 (m, 2H).

^{13}C NMR (125 MHz**, CDCl3) δ** 148.5, 134.9, 131.919, 127.8, 126.7, 71.1, 62.3, 51.5, 34.3, 24.6, 5.6, 5.5.

HRMS: Calculated for $C_{13}H_{16}BrN_2O_3S$ $(M-H)^+$ 359.0065; Found 359.0060 (EI).

(*S*)-4-bromo-*N*-(4-chlorobenzyl)-2-(3-hydroxypyrrolidin-1-yl)benzenesulfonamide



Clear oil (121 mg, 86%)

FTIR (thin Film): 3450, 3292, 2880, 1597, 1451, 1380, 1164 cm^{-1}

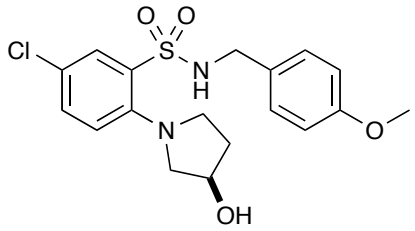
$[\alpha]_D^{20}$ -4.92 (*c* = 0.65, $CHCl_3$)

^{1}H NMR (500 MHz, CDCl3) δ 7.86 (d, *J* = 8.4, 1H), 7.37 (dd, *J* = 8.4, 1.9 Hz, 1H), 7.34 (d, *J* = 1.9 Hz, 1H), 7.20 – 7.16 (m, 2H), 7.07 (d, *J* = 8.5 Hz, 2H), 6.98 (t, *J* = 6.3 Hz, 1H), 4.47 (s, 1H), 3.93 (qd, *J* = 14.2, 6.3 Hz, 2H), 3.43 (d, *J* = 10.4 Hz, 1H), 3.33 (td, *J* = 8.8, 4.1 Hz, 1H), 2.93 – 2.81 (m, 2H), 2.32 (t, *J* = 10.0 Hz, 1H), 2.26 – 2.17 (m, 1H), 1.83 (ddd, *J* = 14.0, 8.4, 7.0 Hz, 1H).

^{13}C NMR (125 MHz**, CDCl3) δ** 148.2, 134.9, 134.7, 133.5, 131.4, 129.4, 128.5, 127.7, 127.5, 126.2, 71.0, 62.0, 51.3, 47.0, 34.1.

HRMS: Calculated for $C_{17}H_{17}BrClN_2O_3S$ Calculated for 442.9832 $(M-H)^+$: Found 442.9836 (EI).

(S)-5-chloro-2-(3-hydroxypyrrolidin-1-yl)-N-(4-methoxybenzyl)benzenesulfonamide



Clear oil (151 mg, 72%)

FTIR (thin Film): 3488, 3315, 29987, 1602, 1388, 1164 cm^{-1}

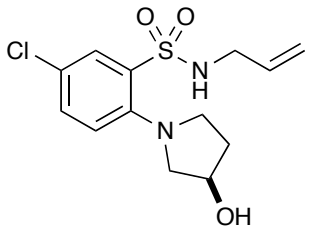
$[\alpha]_D^{20}$ -9.0 ($c = 0.9$, $CHCl_3$)

^{1}H NMR (500 MHz, CDCl3) δ 7.99 – 7.95 (m, 1H), 7.44 (dd, *J* = 8.5, 2.5 Hz, 1H), 7.17 (d, *J* = 8.6 Hz, 1H), 7.01 (d, *J* = 8.5 Hz, 2H), 6.72 (d, *J* = 8.2 Hz, 2H), 4.47 – 4.42 (m, 1H), 3.97 (q, *J* = 13.8 Hz, 2H), 3.74 (s, 3H), 3.27 (dd, *J* = 11.3, 6.9 Hz, 2H), 2.90 – 2.79 (m, 2H), 2.19 (ddd, *J* = 13.9, 9.9, 5.4 Hz, 2H), 1.86 – 1.76 (m, 1H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 159.1, 145.8 137.9, 133.2, 130.1, 129.8, 129.5, 128.3, 124.5, 113.7, 71.0, 62.3, 55.2, 51.7, 47.4, 34.3.

HRMS: Calculated for $C_{18}H_{20}ClN_2O_4S$ Calculated for 395.0832 $(M-H)^+$: Found 395.0828 (EI).

N-allyl-5-chloro-2-((3R)-3-hydroxycyclopentyl)benzenesulfonamide



FTIR (thin Film): 3498, 3300, 2980, , 1597, 1386, 1164

Clear oil (90 mg, 78%)

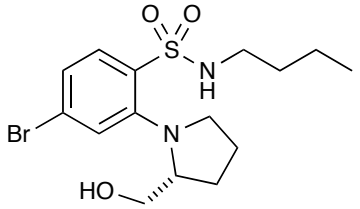
$[[\alpha]_D^{20}$ -10.52 (*c* = 1.15, $CHCl_3$)

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.91 (d, *J* = 2.5 Hz, 1H), 7.41 (dd, *J* = 8.5, 2.5 Hz, 1H), 7.18 (d, *J* = 8.6 Hz, 1H), 7.08 (dd, *J* = 1.8, 0.8 Hz, 1H), 6.11 (dd, *J* = 3.2, 1.9 Hz, 1H), 5.97 (d, *J* = 3.2 Hz, 1H), 4.56 – 4.48 (m, 1H), 4.12 (q, *J* = 15.3 Hz, 2H), 3.38 (td, *J* = 8.7, 4.5 Hz, 1H), 3.25 (d, *J* = 10.3 Hz, 1H), 2.92 (dd, *J* = 10.3, 3.6 Hz, 1H), 2.87 (dd, *J* = 15.8, 9.1 Hz, 1H), 2.25 (dddd, *J* = 13.8, 9.2, 6.2, 4.5 Hz, 2H), 1.92 (ddd, *J* = 13.8, 8.3, 6.8 Hz, 2H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 149.6, 146.0, 142.1, 138.3, 133.1, 130.2, 129.4, 124.6, 110.3, 108.6, 71.1, 62.2, 51.8, 40.3, 34.4

HRMS: Calculated for $C_{13}H_{16}ClN_2O_3S$ Calculated for 315.1570 $(M-H)^+$: Found 315.0566 (EI).

(*R*)-4-bromo-*N*-butyl-2-(2-(hydroxymethyl)pyrrolidin-1 yl)benzenesulfonamide



Clear oil (211 mg, 91%)

FTIR (Thin Film): 3450, 3310, 2950, 1603, 1460, 1349, 1160 cm^{-1}

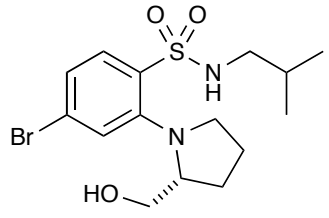
$[\alpha]_D^{20}$ 25.1 (*c* = 2.0, $CHCl_3$)

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.82 (d, *J* = 8.5 Hz, 1H), 7.48 (d, *J* = 1.9 Hz, 1H), 7.39 (dd, *J* = 8.5, 1.9 Hz, 1H), 6.10 (t, *J* = 6.2 Hz, 1H), 3.63 – 3.59 (m, 1H), 3.56 (dd, *J* = 8.0, 4.1 Hz, 1H), 3.48 (s, 2H), 2.88 – 2.85 (m, 1H), 2.85 – 2.74 (m, 3H), 2.07 (qd, *J* = 10.2, 4.6 Hz, 1H), 1.96 – 1.88 (m, 3H), 1.50 – 1.43 (m, 2H), 1.34 – 1.26 (m, 2H), 0.89 – 0.84 (t 7.4 Hz, 3H).

^{13}C NMR (125 MHz**, $CDCl_3$) δ** 151.3, 136.7, 131.1, 128.7, 128.3, 127.7, 65.5, 62.3, 58.4, 43.5, 31.9, 26.5, 24.3, 19.8, 13.6.

HRMS calculated for $C_{15}H_{23}BrNO_3SNa$ $(M+Na)^+$ 413.0510; found 413.0511 (EI).

(*R*)-4-bromo-2-(2-(hydroxymethyl)pyrrolidin-1-yl)-*N*-isobutylbenzenesulfonamide



Clear oil (143 mg, 88%)

FTIR (neat): 2978, 1610, 1484, 1354, 1338, 1164 cm^{-1}

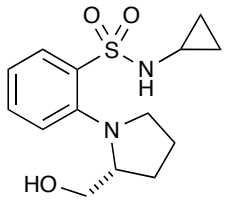
$[\alpha]_D^{20}$ 41.5 (*c* = 0.65, $CHCl_3$)

1H NMR (500 MHz, $CDCl_3$) δ 7.82 – 7.78 (m, 1H), 7.48 (d, *J* = 1.9 Hz, 1H), 7.38 (dd, *J* = 8.5, 1.9 Hz, 1H), 6.14 (t Hz, *J* = 6.5, 1H), 3.63 – 3.58 (m, 1H), 3.57 – 3.54 (m, 1H), 3.48 (d, *J* = 4.6 Hz, 2H), 2.91 – 2.86 (m, 1H), 2.85 – 2.82 (m, 1H), 2.65 – 2.55 (m, 2H), 2.11 – 2.02 (m, 1H), 1.96 – 1.87 (m, 3H), 1.75 (td, *J* = 13.4, 6.7 Hz, 1H), 0.88 (dt, *J* = 10.9, 5.4 Hz, 6H).

13C NMR (125 MHz**, $CDCl_3$) δ** 151.2, 136.7, 131.0, 128.7, 128.3, 127.7, 65.6, 62.3, 58.3, 50.9, 28.9, 26.4, 24.3, 20.0, 19.9.

HRMS calculated for $C_{15}H_{23}BrN_2O_3SNa$ $(M+Na)^+$ 413.0510; found 413.0500 (EI).

(*R*)-*N*-cyclopropyl-2-(2-(hydroxymethyl)pyrrolidin-1-yl)benzenesulfonamide



Clear oil (159mg, 87%)

FTIR (Thin Film): 3480, 3320, 2995, 1600, 1454, 1357, 1332. 1158 cm^{-1}

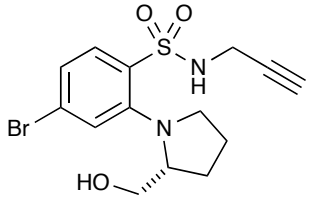
$[\alpha]_D^{20}$ -29.8 (*c* = 1.48, $CHCl_3$)

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.84 (d, *J* = 8.5 Hz, 1H), 7.45 (d, *J* = 1.9 Hz, 1H), 7.36 (dd, *J* = 8.5, 1.9 Hz, 1H), 6.49 (s, 1H), 3.61 – 3.53 (m, 2H), 3.49 – 3.38 (m, 2H), 2.84 – 2.77 (m, 1H), 2.55 (t, *J* = 5.6 Hz, 1H), 2.08 – 1.96 (m, 2H), 1.92 – 1.82 (m, 3H), 0.74 – 0.63 (m, 1H), 0.58 – 0.41 (m, 3H).

^{13}C NMR (125 MHz**, $CDCl_3$) δ** 151.4, 136.4, 131.7, 128.9, 128.5, 128.1, 65.5, 62.4, 58.6, 26.6, 25.0, 24.4, 6.1, 5.8.

HRMS calculated for $C_{14}H_{19}BrN_2O_3SNa$ $(M+Na)^+$ 397.0197; found 397.0192 (EI).

(*R*)-4-bromo-2-(2-(hydroxymethyl)pyrrolidin-1-yl)-*N* (propynyl)benzenesulfonamide



Clear oil (215 mg, 92%)

FTIR (Thin Film): 3471, 3321, 3080, 2221, 1603, 1460, 1349, 1158 cm^{-1}

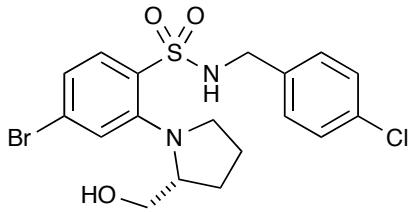
$[\alpha]_D^{20}$ -31.0 (*c* = 1.6, $CHCl_3$)

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.84 (d, *J* = 8.5 Hz, 1H), 7.46 (d, *J* = 1.9 Hz, 1H), 7.39 (dd, *J* = 8.4, 1.9 Hz, 1H), 7.22 – 7.17 (m, 1H), 3.81 (ddd, *J* = 17.7, 7.4, 2.5 Hz, 1H), 3.76 (dd, *J* = 8.4, 3.8 Hz, 1H), 3.73 (dd, *J* = 5.3, 2.6 Hz, 1H), 3.69 (dd, *J* = 5.3, 2.5 Hz, 0H), 3.68 – 3.62 (m, 2H), 3.56 (dt, *J* = 9.9, 4.5 Hz, 1H), 2.85 – 2.78 (m, 1H), 2.28 (t, *J* = 4.8 Hz, 1H), 2.12 – 2.03 (m, 1H), 1.98 – 1.87 (m, 4H).

^{13}C NMR (125 MHz**, $CDCl_3$) δ** 151.2, 137.4, 131.1, 128.2, 128.0, 127.7, 78.5, 72.2, 64.3, 61.8, 58.7, 33.4, 26.4, 24.0.

HRMS calculated for $C_{14}H_{16}BrN_2O_3SNa$ $(M-H)^+$ 371.0065; found 371.0068 (EI).

(R)-4-bromo-N-(4-chlorobenzyl)-2-(2-(hydroxymethyl)pyrrolidin-1 yl)benzenesulfonamide



Clear oil (115 mg, 86%)

FTIR (Thin Film): 3460, 3350, 3010, 2950, 1610, 1585, 1480, 1354, 1328, 1158 cm^{-1}

$[\alpha]_D^{20}$ -37.5 (*c* = 0.8, $CHCl_3$)

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.81 (d, *J* = 8.4 Hz, 1H), 7.44 (d, *J* = 1.8 Hz, 1H), 7.39 (dd, *J* = 8.4, 1.9 Hz, 1H), 7.24 – 7.18 (m, 4H), 6.97 (t, *J* = 6.5 Hz, 1H), 4.06 (dd, *J* = 14.4, 7.1 Hz, 1H), 3.83 (dd, *J* = 14.4, 5.9 Hz, 1H), 3.66 – 3.57 (m, 2H), 3.48 – 3.42 (m, 2H), 2.82 (dt, *J* = 10.3, 7.0 Hz, 1H), 2.16 (t, *J* = 5.2 Hz, 1H), 2.05 (ddd, *J* = 14.3, 11.4, 7.6 Hz, 1H), 1.91 – 1.77 (m, 3H).

^{13}C NMR (125 MHz**, $CDCl_3$) δ** 151.3, 136.6, 135.8, 133.3, 131.1, 129.1, 128.5, 128.3, 128.2, 127.8, 64.7, 62.3, 58.3, 46.9, 26.5, 24.1.

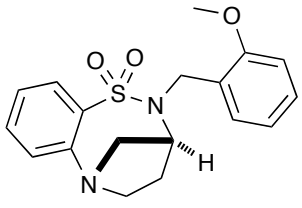
HRMS calculated for $C_{18}H_{20}BrClN_2O_3SNa$ $(M+Na)^+$480.9964; found 480.9962 (EI).

Representative Procedure for intramolecular Mitsunobu ring closure.

To a flame dried Rb flask under argon was added (R)-4-bromo-2-(3-hydroxypyrrolidin-1-yl)-N-(prop-2-yn-1-yl)benzenesulfonamide (80 mg, 0.22 mmol), PPh_3 (87 mg, 0.33 mmol) and THF (2.2 ml, 0.1M) and stirred. After the PPh_3 was completely dissolved, DIAD (54 mg, 53 μL, 0.27 mmol) was added slowly drop wise. The reaction was stirred for 10 minutes, concentrated under reduced pressure and subjected to flash chromatography to afford (3R,6S)-8-bromo-2-(prop-2-yn-1-yl)-2,3,4,5-tetrahydro-3,6-methanobenzo[g][1,2,6]thiadiazocine 1,1-dioxide (48 mg, 67%) as a clear oil.

(3R,6S)-2-(2-methoxybenzyl)-2,3,4,5-tetrahydro-3,6

methanobenzo[g][1,2,6]thiadiazocine 1,1-dioxide



Clear oil (52 mg, 71%)

FTIR (Thin Film): 3030, 2960, 1600, 1461, 1351, 1231, 1162 cm^{-1}

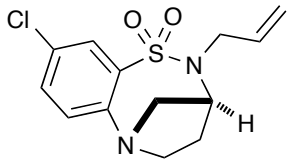
$[\alpha]_D^{20}$ -2.92 (*c* = 0.61, $CHCl_3$)

^{1}H NMR (500 MHz, C_6D_6) δ 7.87 (d, *J* = 7.8 Hz, 2H), 7.06 (t, *J* = 7.8 Hz, 1H), 7.00 (t, *J* = 7.8 Hz, 1H), 6.93 (t, *J* = 7.5 Hz, 1H), 6.48 – 6.40 (m Hz, 2H), 6.09 (d, *J* = 8.4 Hz, 1H), 5.71 (dd, *J* = 8.8, 6.5 Hz, 1H), 4.66 (d, *J* = 17.7 Hz, 1H), 3.94 (d, *J* = 17.8 Hz, 1H), 3.10 (s, 3H), 2.56 (dd, *J* = 8.9, 6.7 Hz, 1H), 2.47 (dd, *J* = 16.3, 9.1 Hz, 1H), 1.40 (dt, *J* = 20.4, 8.3 Hz, 2H), 1.17 – 1.04 (m Hz, 1H), 0.95 (dt, *J* = 14.3, 9.2, 1H).

^{13}C NMR (125 MHz, C_6D_6) δ 156.5, 141.9, 133.6, 129.2, 128.7, 127.5, 127.0, 121.5, 120.3, 116.8, 113.2, 110.2, 75.1, 54.9, 46.3, 41.5, 29.3, 21.8.

HRMS calculated for $C_{18}H_{20}N_2O_3SNa$ $(M+Na)^+$ 367.1092; found 367.1090 (EI).

(3R,6S)-2-allyl-9-chloro-2,3,4,5-tetrahydro-3,6-methanobenzo[g][1,2,6]thiadiazocine 1,1-dioxide



Clear oil (121 mg, 61%)

FTIR (Thin Film): 31150, 2880, 1640, 1603, 1461, 1351, 1331, 1164 cm^{-1}

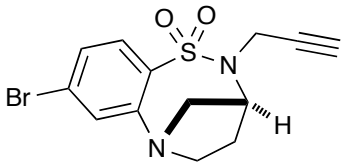
$[\alpha]_D^{20}$ -1.94 (*c* = 1.1, $CHCl_3$)

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.65 (d, *J* = 2.5, 1H), 7.25 (dd, *J* = 8.9, 2.5 Hz, 1H), 7.23 (dd, *J* = 1.8, 0.8, Hz 1H), 6.43 (d, *J* = 8.9 Hz, 1H), 6.20 – 6.17 (m Hz, 2H), 5.68 (t, *J* = 7.6 Hz, 1H), 4.28 (d, *J* = 16.7 Hz, 1H), 4.08 (d, *J* = 16.7 Hz, 1H), 3.46 (ddd, *J* = 11.4, 6.4, 2.0 Hz, 1H), 3.28 (td, *J* = 9.2, 7.2 Hz, 1H), 2.39 – 2.30 (m Hz, 2H), 2.28 – 2.17 (m Hz, 1H), 2.09 – 1.95 (m Hz, 1H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 149.9, 141.9, 139.6, 133.5, 125.3, 121.2, 119.5, 114.2, 110.5, 109.0, 74.0, 46.4, 39.9, 28.4, 21.8.

HRMS calculated for $C_{13}H_{15}ClN_2O_2SNa$ $(M+Na)^+$ 321.0040; found 321.0045 (EI).

(3R,6S)-8-bromo-2-(prop-2-yn-1-yl)-2,3,4,5-tetrahydro-3,6-methanobenzo[g][1,2,6]thiadiazocine 1,1-dioxide



Clear oil (48 mg, 67%)

FTIR (Thin Film): 3080, 2905, 2120, 1610, 1435, 1355, 1342, 1161 cm^{-1}

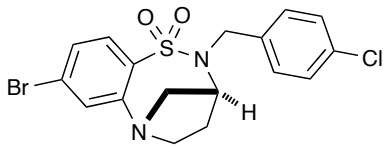
$[\alpha]_D^{20}$ 2.234 (*c* = 0.55, $CHCl_3$)

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.52 (d, *J* = 8.4 Hz, 1H), 6.90 (dd, *J* = 8.4, 1.7 Hz, 1H), 6.70 (d, *J* = 1.7 Hz, 1H). 5.70 (dd, *J* = 8.5, 6.5 Hz, 1H), 3.92 (qd, *J* = 18.5, 2.6 Hz, 2H), 3.53 (td, *J* = 8.8, 2.6 Hz, 1H), 3.28 (td, *J* = 9.2, 7.1 Hz, 1H), 2.45 – 2.31 (m, 2H), 2.31 – 2.21 (m, 1H), 2.15 – 2.05 (m, 1H), 2.03 (t, *J* = 2.5 Hz, 1H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 142.6, 128.4, 126.9, 119.3, 117.8, 115.5, 77.4, 73.5, 72.4, 46.9, 33.0, 28.5, 22.2.

HRMS calculated for $C_{13}H_{13}N_2O_2SNa$ $(M+Na)^+$ 362.9779; found 362.9776 (EI).

(3R,6S)-8-bromo-2-(4-chlorobenzyl)-2,3,4,5-tetrahydro-3,6-methanobenzo[g][1,2,6]thiadiazocine 1,1-dioxide



Clear oil (62 mg, 72%)

FTIR (Thin Film): 2930, 1601, 1580, 1488, 1367, 1341, 1226, 1164 cm^{-1}

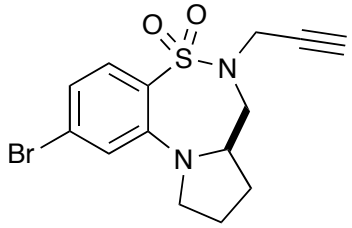
$[\alpha]_D^{20}$ + 12.0 (*c* = 0.66, $CHCl_3$)

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.57 (d, *J* = 8.4 Hz, 1H), 7.30 (s, 4H), 6.95 (dd, *J* = 8.4, 1.7 Hz, 1H), 6.80 (d, *J* = 1.7 Hz, 1H), 5.75 (dd, *J* = 9.1, 6.1 Hz, 1H), 4.41 (d, *J* = 16.7 Hz, 1H), 3.66 (d, *J* = 16.7 Hz, 1H), 3.53 (td, *J* = 9.1, 2.4 Hz, 1H), 3.38 (dt, *J* = 16.4, 8.2 Hz, 1H), 2.20 – 2.07 (m, 2H), 2.05 – 1.92 (m, 1H), 1.89 – 1.78 (m, 1H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 141.9, 136.2, 133.2, 128.8, 128.5, 128.2, 127.6, 119.6, 117.2, 115.6, 74.7, 46.6, 45.7, 29.1, 21.7.

HRMS calculated for $C_{17}H_{16}ClBrN_2O_2SNa$ $(M+Na)^+$ 448.9702; found 448.9700 (EI).

(R)-2-bromo-6-(prop-2-yn-1-yl)-6,7,7a,8,9,10-hexahydrobenzo[f]pyrrolo[2,1-d][1,2,5]thiadiazepine 5,5-dioxide



Clear oil (94 mg, 81%)

FTIR (Thin Film): 3180, 2985, 2128, 1605, 1457, 1365, 1158 cm^{-1}

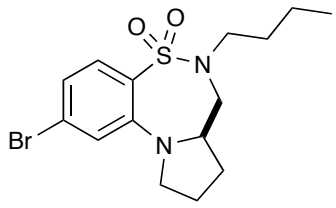
$[\alpha]_D^{20}$ + 69.31.5 (*c* = 2.0, $CHCl_3$)

^{1}H NMR (500 MHz, $CDCl_3$): δ 7.65 (d, *J* = 8.5 Hz, 1H), 6.98 (d, *J* = 8.5 Hz, 1H), 6.95 (s, 1H), 4.44 (s, 1H), 4.05 – 3.97 (m, 2H), 3.59 (dd, *J* = 13.2, 3.1 Hz, 1H), 3.43 – 3.26 (m, 3H), 2.23 (t, *J* = 2.5 Hz, 1H), 2.18 – 2.02 (m, 3H), 1.78 – 1.69 (m, 1H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 146.4, 130.6, 127.7, 126.2, 118.4, 118.3, 77.3, 73.6, 59.3, 54.5, 51.2, 39.9, 30.1, 23.4.

HRMS calculated for $C_{14}H_{15}BrN_2O_2SNa$ $(M+Na)^+$ 376.9935; found 376.9945 (EI).

(R)-2-bromo-6-butyl-6,7,7a,8,9,10-hexahydrobenzo[f]pyrrolo[2,1-d][1,2,5]thiadiazepine 5,5-dioxide



Clear oil (143 mg, 91%)

FTIR (Thin film): 2987, 1601, 1458, 1359, 1329, 1254, 1158 cm^{-1}

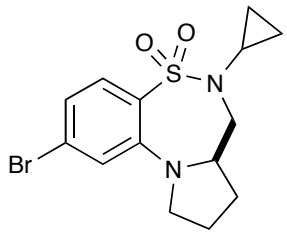
$[\alpha]_D^{20}$ + 69.3(*c* = 1.5, $CHCl_3$)

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.67 (d, *J* = 8.4 Hz, 1H), 7.00 (d, *J* = 8.4 Hz, 1H), 6.96 (s, 1H), 4.31 (s, 1H), 3.46 (s, 1H), 3.34 (ddd, *J* = 25.0, 13.9, 8.6 Hz, 2H), 3.07 (s, 3H), 2.15 – 1.94 (m, 3H), 1.69 (dd, *J* = 11.9, 4.6 Hz, 1H), 1.58 – 1.47 (m, 2H), 1.39 – 1.23 (m, 2H), 0.90 (t, *J* = 7.4 Hz, 3H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 146.6, 130.9, 127.2, 121.8, 118.4, 118.2, 59.4 55.1, 51.2, 49.9, 30.7, 29.8, 23.4, 19.6, 13.7.

HRMS calculated for $C_{15}H_{21}BrN_2NaO_2S$ $(M+Na)^+$ 395.0405; found 395.0400 (EI).

(R)-2-bromo-6-cyclopropyl-6,7,7a,8,9,10-hexahydrobenzo[f]pyrrolo[2,1-d][1,2,5]thiadiazepine 5,5-dioxide



Clear oil (119 mg, 75%)

FTIR (neat): 2950, 1603, 1460, 1349, 1158 cm^{-1}

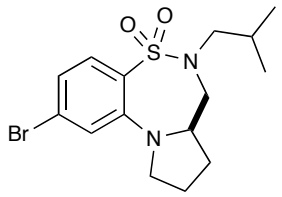
$[\alpha]_D^{20}$ + 69.3 (*c* = 0.98, $CHCl_3$)

^{1}H NMR (500 MHz, $CDCl_3$) δ7.73 (d, *J* = 8.5 Hz, 1H), 7.04 (dd, *J* = 8.5, 1.7 Hz, 1H), 7.00 (s, 1H), 4.30 (s, 1H), 3.50 (t, *J* = 11.5, 1H), 3.39 (dd, *J* = 9.1, 4.1, 1H), 3.36 – 3.30 (m, 1H), 3.26 (s, 1H), 2.40 – 2.32 (m, 1H), 2.14 – 2.00 (m, 3H), 1.74 – 1.66 (m, 1H), 0.91 (s, 1H), 0.79 (s, 1H), 0.72 – 0.62 (m, 2H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 146.7, 131.4, 127.6, 126.3, 122.1, 118.7, 59.2, 58.1, 51.4, 31.8, 30.0, 23.5, 8.9, 7.6.

HRMS calculated for $C_{14}H_{17}BrN_2O_3SNa$ $(M+Na)^+$ 379.0092; found 379.0081 (EI).

R)-2-bromo-6-isobutyl-6,7,7a,8,9,10-hexahydrobenzo[f]pyrrolo[2,1-d][1,2,5]thiadiazepine 5,5-dioxide



Clear oil (143 mg, 87%)

FTIR (neat): 2950, 1603, 1460, 1349, 1158 cm^{-1}

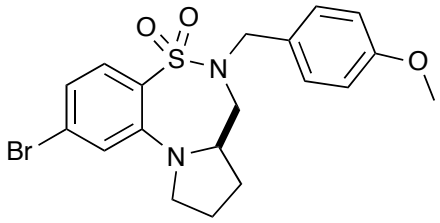
$[\alpha]_D^{20}$ + 69.5 (*c* = 2.25, $CHCl_3$)

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.67 (d, *J* = 8.4 Hz, 1H), 7.01 (d, *J* = 8.4 Hz, 1H), 6.97 (s, 1H), 4.33 (broad s, 1H), 3.49 (broad s, 1H), 3.37 (dd, *J* = 9.8, 5.1 Hz, 1H), 3.34 – 3.26 (m, 1H), 3.04 (s, 1H), 2.84 (d, *J* = 6.0 Hz, 2H), 2.15 – 1.95 (m, 3H), 1.92 – 1.81 (m, 1H), 1.72 – 1.65 (m, 1H), 0.91 (dd, *J* = 11.2, 6.7 Hz, 6H).

^{13}C NMR (125 MHz, $CDCl_3$) 146.6, 131.0, 127.2, 121.8, 118.4, 59.6, 57.7, 56.1, 51.2, 29.7, 27.9, 23.4, 20.0, 19.8.

HRMS calculated for $C_{15}H_{21}BrN_2O_3SNa$ $(M+Na)^+$ 395.0405; found 395.0407 (EI).

(R)-2-bromo-6-(4-methoxybenzyl)-6,7,7a,8,9,10-hexahydrobenzo[f]pyrrolo[2,1-d][1,2,5]thiadiazepine 5,5-dioxide



Clear oil (112 mg, 77%)

FTIR (Thin Film): 3199, 3090, 1602, 1475, 1388, 1337, 1166 cm^{-1}

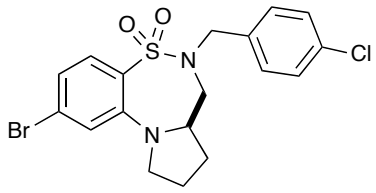
$[\alpha]_D^{20}$ + 63.8 (*c* = 1.32, $CHCl_3$)

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.72 (d, *J* = 8.5 Hz, 1H), 7.18 (d, *J* = 8.6 Hz, 2H), 7.04 – 7.00 (m, 1H), 6.92 (s, 1H), 6.87 – 6.81 (m, 2H), 4.34 (broad s, 1H), 4.27 (broad s, 1H), 4.21 (broad s, 1H), 3.79 (s, 3H), 3.32 (s, 1H), 3.27 (d, *J* = 6.5 Hz, 2H), 2.98 (s, 1H), 2.07 – 1.97 (m, 2H), 1.96 – 1.85 (m, 1H), 1.59 (t, *J* = 5.7 Hz, 1H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 159.3, 146.6, 130.8, 129.8, 127.7, 127.4, 127.2, 121.2, 118.3, 113.9, 59.5, 55.3, 53.7, 53.3, 51.1, 29.8, 23.5.

HRMS calculated for $C_{19}H_{21}BrN_2O_3SNa$ $(M+Na)^+$ 459.0354; found 459.0344 (EI).

(R)-2-bromo-6-(4-chlorobenzyl)-6,7,7a,8,9,10-hexahydrobenzo[f]pyrrolo[2,1-d][1,2,5]thiadiazepine 5,5-dioxide



Clear oil (81 mg, 72%)

FTIR (Thin Film): 3102, 1604, 1593, 1487, 1450, 1368, 1341, 1164 cm^{-1}

$[\alpha]_D^{20}$ + 61.3 (*c* = 0.8, $CHCl_3$)

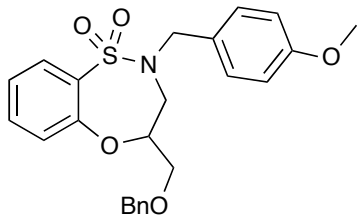
^{1}H NMR (500 MHz, $CDCl_3$) δ 7.71 (d, *J* = 8.5, 1H), 7.31 – 7.28 (m, 2H), 7.22 (d, *J* = 8.4, 2H), 7.04 (dd, *J* = 8.5, 1.5, 1H), 6.96 (s, 1H), 4.32 (s, 2H), 4.23 (s, 1H), 3.35 (s, 1H), 3.30 (d, *J* = 8.7, 2H), 2.94 (s, 1H), 2.03 (dt, *J* = 6.5, 6.0, 2H), 1.92 (td, *J* = 10.2, 5.3, 1H), 1.61 (dd, *J* = 11.0, 5.7, 1H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 146.5, 134.4, 133.8, 130.7, 129.6, 128.76, 127.6, 127.0, 121.9, 118.4, 59.6, 54.2, 53.2, 51.1, 29.7, 23.4.

HRMS calculated for $C_{18}H_{18}ClN_2O_2SNa$ $(M+Na)^+$ 462.9859; found 462.9850 (EI).

General Procedure A Sequential epoxide ring-opening, S_NAr ring-closing protocol: To a microwave vial was added sulfonamide (0.8 mmol, 1eq.), benzyltriethylammonium chloride (0.16mmol, 0.2 eq.), potassium carbonate (0.16mmol. 0.2 equiv.), epoxide (0.72mmol, 0.9 equiv.) and dry dioxane (3M). Reaction vial was placed in Biotage® Initiator microwave and heated at 150 ºC for 13 mins. After such time, cesium carbonate (2.4mmol, 3 eq.) and dry DMF (1M) was directly added to the microwave vial and the reaction was resubmitted at 150 ºC for an additional 13 mins in the microwave. The crude reaction mixture was purified by flash chromatography (1:1 hexane: EtOAc) via direct loading of the crude mixture to afford the desired compound.

4-((benzyloxy)methyl)-2-(4-methoxybenzyl)-3,4-dihydro-2H benzo[b][1,4,5]oxathiazepine-1,1-dioxide



Clear oil (67 mg, 62%)

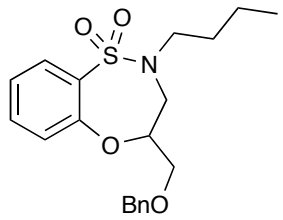
FTIR (neat): 3110, 2950, 1610, 1585, 1453, 1367, 1164 cm^{-1}

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.89 (dd, *J* = 7.8, 1.7, 1H), 7.50 (ddd, *J* = 8.0, 7.5, 1.7, 1H), 7.38 – 7.31 (m, 2H), 7.31 – 7.25 (m, 4H), 7.22 (ddd, *J* = 15.7, 6.7, 1.1, 3H), 6.86 – 6.82 (m, 2H), 4.56 (d, *J* = 12.4, 2H), 4.50 (d, *J* = 14.2, 1H), 4.25 (ddd, *J* = 9.6, 5.7, 4.1, 1H), 3.85 (dd, *J* = 15.3, 11.4, 1H), 3.81 (d, *J* = 5.5, 1H), 3.79 (s, 3H), 3.79 (s, 1H), 3.75 (dd, *J* = 10.3, 5.8, 1H), 3.55 (dd, *J* = 10.3, 5.6, 1H), 3.25 (dd, *J* = 15.2, 1.7, 1H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 159.4, 155.1, 137.6, 134.3, 134.1, 129.9, 129.0, 128.4, 127.8, 127.5, 127.1, 124.4, 123.4, 114.1, 76.8, 73.5, 70.2, 55.3, 51.0, 49.1.

HRMS calculated for $C_{24}H_{25}NO_5SNa$ $(M+Na)^+$ 462.1351; found 462.1352 (EI).

4-((benzyloxy)methyl)-2-butyl-3,4-dihydro-2H-benzo[b][1,4,5]oxathiazepine-1,1-dioxide



Clear oil (68 mg, 67%)

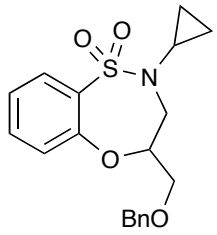
FTIR (neat): 2850, 1602, 1487, 1454, 1355, 1164 cm^{-1};

^{1}H NMR (500 MHz, CDCl3) δ 7.82 (dd, *J* = 7.8, 1.7 Hz, 1H), 7.49 – 7.44 (m, 1H), 7.40 – 7.30 (m, 5H), 7.22 (td, *J* = 7.6, 1.1 Hz, 1H), 7.17 (dd, *J* = 8.1, 1.0 Hz, 1H), 4.63 (s, 2H), 4.19 (ddd, *J* = 9.9, 5.7, 4.2 Hz, 1H), 4.02 – 3.92 (m, 1H), 3.79 (dd, *J* = 10.2, 5.7 Hz, 1H), 3.62 (dd, *J* = 10.2, 5.7 Hz, 1H), 3.39 (dd, *J* = 15.1, 1.7 Hz, 1H), 3.22 (dt, *J* = 14.1, 7.2 Hz, 1H), 2.72 (ddd, *J* = 13.7, 7.8, 5.9 Hz, 1H), 1.62 – 1.50 (m, 2H), 1.40 – 1.27 (m, 2H), 0.91 (t, *J* = 7.4 Hz, 3H).

^{13}C NMR (125 MHz, CDCl3) δ 155.0, 137.5, 134.1, 134.2, 129.08, 128.5, 127.9, 127.6, 124.27, 123.3, 77.1, 73.6, 70.1, 50.6, 47.8, 30.7, 19.6, 13.6.

HRMS calculated for $C_{20}H_{25}NO_4SNa$ $(M+Na)^+$ 398.1402; found 398.1399 (EI).

4-((benzyloxy)methyl)-2-cyclopropyl-3,4-dihydro-2*H*-benzo[*b*][1,4,5]oxathiazepine-1,1-dioxide



Clear oil (58 mg, 66%)

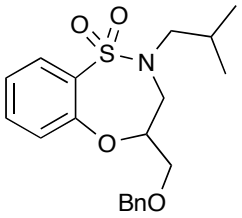
FTIR (neat): 2932, 1602, 1459, 1557, 1351, 1331, 1164 cm^{-1};

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.89 (dd, *J* = 7.8, 1.7 Hz, 1H), 7.50 (ddd, *J* = 8.0, 7.5, 1.7 Hz, 1H), 7.40 – 7.35 (m, 4H), 7.32 (ddd, *J* = 8.6, 4.0, 2.2 Hz, 1H), 7.27 – 7.23 (m, 1H), 7.21 (dd, *J* = 8.1, 1.0 Hz, 1H), 4.64 (s, 2H), 4.34 (ddd, *J* = 11.0, 7.0, 1.7 Hz, 1H), 4.04 (dd, *J* = 14.9, 10.8 Hz, 1H), 3.80 (dd, *J* = 10.3, 5.9 Hz, 1H), 3.64 (dd, *J* = 10.3, 5.2 Hz, 1H), 3.43 (dd, *J* = 14.9, 1.7 Hz, 1H), 2.13 (tt, *J* = 6.8, 3.5 Hz, 1H), 1.20 – 1.12 (m, 1H), 0.84 (ddd, *J* = 12.4, 9.7, 6.8 Hz, 1H), 0.69 – 0.58 (m, 2H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 155.1, 137.6, 134.4, 133.2, 129.8, 128.5, 127.9, 127.7, 124.4, 123.5, 77.1, 73.6, 70.4, 53.8, 29.9, 10.1, 6.7.

HRMS calculated for $C_{19}H_{21}NO_4SNa$ $(M+Na)^+$ 382.1089; found 382.1092 (EI).

4-((benzyloxy)methyl)-2-isobutyl-3,4-dihydro-2H-benzo[b][1,4,5]oxathiazepine-1,1-dioxide



Clear oil (72 mg, 62%)

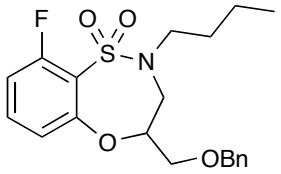
FTIR (neat): 2954, 1610, 1441, 1554, 1361, 1337, 1161 cm^{-1}

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.82 (dd, *J* = 7.8, 1.7 Hz, 1H), 7.47 (ddd, *J* = 8.0, 7.5, 1.7 Hz, 1H), 7.40 – 7.30 (m, 5H), 7.22 (td, *J* = 7.6, 1.1 Hz, 1H), 7.17 (dd, *J* = 8.1, 1.0 Hz, 1H), 4.63 (d, *J* = 1.5 Hz, 2H), 4.24 – 4.16 (m, 1H), 3.98 (dd, *J* = 14.4, 10.7 Hz, 1H), 3.78 (dd, *J* = 10.2, 5.7 Hz, 1H), 3.61 (dd, *J* = 10.2, 5.6 Hz, 1H), 3.36 (dd, *J* = 15.1, 1.7 Hz, 1H), 2.95 (ddd, *J* = 13.7, 8.2, 1.0 Hz, 1H), 2.52 (dd, *J* = 13.7, 6.7 Hz, 1H), 1.91 (dp, *J* = 20.0, 6.7 Hz, 1H), 0.94 (dd, *J* = 17.5, 6.7 Hz, 6H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 155.0, 137.5, 134.1, 134.0, 129.2, 128.5, 127.9, 127.7, 124.3, 123.3, 77.2, 73.6, 70.1, 55.5, 51.4, 27.7, 20.0, 19.8.

HRMS calculated for $C_{20}H_{25}NO_4SNa$ $(M+Na)^+$ 398.1402; found 398.1404 (EI).

4-(Benzyloxymethyl)-2-butyl-9-fluoro-1,2-benzoxathiazepine-1,1-dioxide



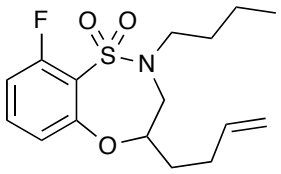
FTIR (neat): 2956, 1604, 1461, 1350, 1161 cm^{-1};

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.39 – 7.33 (m, 5H), 7.32 – 7.28 (m, 1H), 6.94 (d, *J* = 8.3 Hz, 1H), 6.90 (ddd, *J* = 9.4, 6.4, 1.0 Hz, 1H), 4.68 (dt, *J* = 9.6, 4.6 Hz, 1H), 4.61 (q, *J* = 12.1 Hz, 2H), 3.72 – 3.63 (m, 2H), 3.62 – 3.50 (m, 2H), 3.29 (dt, *J* = 14.5, 7.4 Hz, 1H), 3.21 – 3.15 (m, 1H), 1.64 – 1.54 (m, 2H), 1.39 – 1.31 (m, 2H), 0.92 (t, *J* = 7.4 Hz, 3H);

^{13}C NMR (125 MHz, $CDCl_3$) δ 158.2 (d, $^{1}J_{C\text{-}F}$ = 337.1 Hz), 154.3 (d, $^{3}J_{C\text{-}F}$ = 2.5 Hz), 135.3, 130.99, 126.2, 125.5, 125.3, 115.6, 110.0, 109.7, 79.0, 71.2, 67.6, 48.0, 47.2, 28.3, 17.3, 11.6;

HRMS calculated for $C_{20}H_{24}FNO_4SNa$ $(M+Na)^+$ 416.1308; found 416.1303 (EI).

4-(But-3-enyl)-2-butyl-9-fluoro-1,2-benzoxathiazepine-1,1-dioxide



(Colorless oil, 143 mg, 73%)

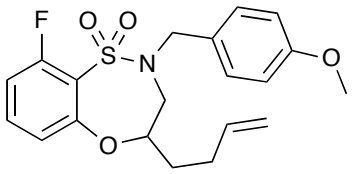
FTIR (neat): 2952, 1604, 1453, 1351, 1160 cm^{-1};

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.38 – 7.32 (m, 1H), 6.92 – 6.84 (m, 2H), 5.81 – 5.71 (m, 1H), 5.02 – 4.94 (m, 2H), 4.52 – 4.45 (m, 1H), 3.57 (dd, *J* = 14.2, 3.6 Hz, 1H), 3.34 – 3.26 (m, 2H), 3.15 (ddd, *J* = 13.9, 7.8, 6.1 Hz, 1H), 2.38 – 2.29 (m, 1H), 2.18 (ddt, *J* = 14.4, 8.3, 7.2 Hz, 1H), 1.87 – 1.78 (m, 1H), 1.67 – 1.60 (m, 1H), 1.60 – 1.51 (m, 2H), 1.38 – 1.29 (m, 2H), 0.90 (t, *J* = 7.4 Hz, 3H);

^{13}C NMR (125 MHz, $CDCl_3$) δ 160.0 (d, $^{1}J_{C\text{-}F}$ = 250.1 Hz), 157.0 (d, $^{3}J_{C\text{-}F}$ = 2.5 Hz), 137.0, 133.2, 122.73, 117.4, 112.0, 111.8, 82.0, 53.5, 50.5, 32.8, 31.0, 29.4, 19.6, 13.4;

HRMS calculated for $C_{16}H_{22}FNO_3SNa$ $(M+Na)^+$ 350.1202; found 350.1198 (EI).

4-(But-3-enyl)-9-fluoro-2-(4-methoxybenzyl)-1,2-benzoxathiazepine-1,1-dioxide



(Colorless oil, 133 mg, 69%)

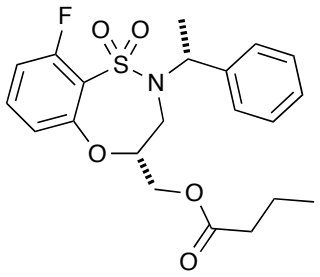
FTIR (neat) 2955, 1465, 1352, 1254, 1160 cm^{-1}:

^{1}H **NMR** (500 MHz, $CDCl_3$) δ = 7.40 (dd, *J* = 8.5, 5.4 Hz, 1H), 7.30 – 7.26 (m, 2H), 6.97 – 6.92 (m, 2H), 6.91 – 6.87 (m, 2H), 5.79 – 5.70 (m, 1H), 5.01 – 4.97 (m, 1H), 4.97 – 4.95 (m, 1H), 4.58 – 4.49 (m, 2H), 4.20 (d, *J* =14.2 Hz, 1H), 3.81 (s, 3H), 3.39 (dd, *J* = 14.4, 3.6 Hz, 1H), 3.22 (dd, *J* = 14.3, 11.5 Hz, 1H), 2.36 – 2.27 (m, 1H), 2.17 (dqd, *J* = 14.5, 7.1, 1.1 Hz, 1H), 1.79 (dtd, *J* = 14.2, 8.8, 5.4 Hz, 1H), 1.60 – 1.52 (m, 1H);

^{13}C **NMR** (125 MHz, $CDCl_3$) δ = 160.3 (d, $^{1}J_{C\text{-}F}$ = 257.8 Hz), 159.5, 157.1 (d, $^{3}J_{C\text{-}F}$ = 2.4 Hz),, 136.8, 133.5 (d, $^{3}J_{C\text{-}F}$ = 10.6 Hz),, 129.89, 127.32, 117.6, 115.97, 114.16, 112.2 (d, $^{2}J_{C\text{-}F}$ = 22.9 Hz), 82.3, 55.3, 53.7, 51.5, 32.8, 29.6.

HRMS calculated for $C_{20}H_{22}FNO_4SNa$ ($M + Na^+$) 414.1152; found 414.1152 (TOF MS ES^+).

(*R*)-9-Fluoro-2-((*R*)-1-phenylethyl)-1,2-benzoxathiazepine-1,1-dioxide)methyl butyrate



(Colorless oil, 160 mg, 76%)

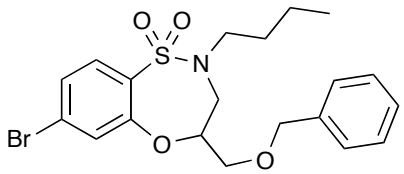
FTIR (neat) 2949, 1746, 1463, 1250, 1168 cm^{-1}:

^{1}H **NMR** (500 MHz, $CDCl_3$) δ = 7.39 – 7.32 (m, 5H), 7.31 – 7.27 (m, 1H), 6.94 (ddd, *J* = 9.5, 6.0, 1.1 Hz, 1H), 6.88 – 6.85 (m, 1H), 5.49 (q, *J* = 7.0 Hz, 1H), 4.57 – 4.49 (m, 1H), 4.19 – 4.12 (m, 2H), 3.26 (dd, *J* = 14.0, 4.0 Hz, 1H), 3.19 (dd, *J* = 13.9, 11.6, 1H), 2.30 (dd, *J* = 7.7, 7.2 Hz, 2H), 1.68 – 1.60 (m, 2H), 1.51 (d, *J* = 7.0 Hz, 3H), 0.93 (t, *J* = 6.9 Hz, 3H);

^{13}C **NMR** (125 MHz, $CDCl_3$) δ = 172.94, 169.1 (d, $^{1}J_{C\text{-}F}$ = 260.5 Hz), 156.5, 139.2, 133.1 (d, $^{2}J_{C\text{-}F}$ = 11.4 Hz), 128.7, 128.1, 127.5, 124.5, 124.3 (d, $^{3}J_{C\text{-}F}$ = 15.2 Hz), 117.3, 112.1 (d, $^{2}J_{C\text{-}F}$ = 22.8 Hz), 79.3, 63.3, 56.9, 44.9, 35.9, 18.3, 16.2, 13.7;

HRMS calculated for $C_{21}H_{24}FNO_5SNa$ (M + Na^+) 444.1257; found 444.1260 (TOF MS ES^+); $[\alpha]^{25}_{D}$ = -8.3 (c = 2.0, $CHCl_3$). $[\alpha]_D^{20}$ **+** 35.0 (*c* = 0.60, $CHCl_3$)

4-(Benzyloxymethyl)-7-bromo-2-butyl-1,2-benzoxathiazepine-1,1-dioxide



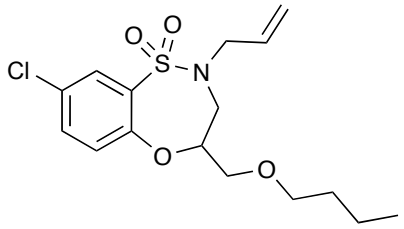
Colorless liquid (145 mg, 65%)

FTIR (neat): 2933, 1604, 1465, 1365, 1161 cm^{-1};

^{1}H **NMR** (500 MHz, $CDCl_3$) δ 7.31 – 7.25 (m, 1H), 7.25 – 7.20 (m, 2H), 6.94 – 6.89 (m, 1H), 6.87 – 6.82 (m, 4H), 4.77 (dt, *J* = 9.5, 4.1 Hz, 2H), 4.15 – 4.10 (m, 1H), 4.05 (dd, *J* = 10.5, 4.0 Hz, 1H), 3.66 – 3.60 (m, 2H), 3.60 – 3.53 (m, 1H), 3.28 – 3.21 (m, 1H), 3.18 – 3.12 (m, 1H), 1.58 – 1.50 (m, 2H), 1.33 – 1.25 (m, 2H), 0.85 (t, *J* = 7.4 Hz, 3H); ^{13}C **NMR** (125 MHz, $CDCl_3$) δ 155.4, 137.4, 133.3, 130.3, 128.6, 128.0, 127.7, 127.5, 127.5, 126.7, 78.2, 74.03, 70.4, 50.77, 48.30, 31.0, 19.9, 13.9.

HRMS calculated for $C_{20}H_{24}BrNO_4SNa$ $(M+Na)^+$ 476.0507; found 476.0502 (EI).

2-Allyl-4-(butoxymethyl)-8-chloro-1,2-benzoxathiazepine-1,1-dioxide



Colorless oil (133 mg, 74%) as a clear oil.

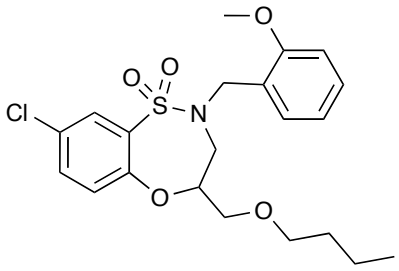
FTIR (neat) 2956, 1465, 1346, 1255, 1168 cm^{-1}:

^{1}H **NMR** (500 MHz, $CDCl_3$) δ = 7.77 (d, *J* = 2.6 Hz, 1H), 7.42 – 7.39 (dd, *J* = 8.5, 2.7 Hz, 1H), 7.11 (d, *J* = 8.6 Hz, 1H), 5.77 (dddd, *J* = 17.2, 10.1, 7.2, 5.1 Hz, 1H), 5.28 – 5.21 (m, 2H), 4.17 – 4.10 (m, 1H), 3.98 – 3.93 (m, 1H), 3.89 (ddd, *J* = 15.2, 10.7, 0.8 Hz, 1H), 3.68 (dd, *J* = 10.4, 5.7 Hz, 1H), 3.53 (dd, *J* = 10.4, 5.6 Hz, 1H), 3.48 (ddd, *J* = 6.5, 4.0, 2.4 Hz, 2H), 3.40 (ddd, *J* = 14.2, 9.8, 4.5 Hz, 2H), 1.55 (ddt, *J* = 13.0, 8.5, 3.6 Hz, 2H), 1.36 (dp, *J* = 9.2, 7.4 Hz, 2H), 0.91 (t, *J* = 7.4 Hz, 3H);

^{13}C **NMR** (125 MHz, $CDCl_3$) δ = 153.6, 135.5, 133.9, 132.2, 129.7, 128.5, 124.9, 119.5, 77.9, 71.6, 70.7, 50.9, 49.6, 31.6, 19.2, 13.9;

HRMS calculated for $C_{16}H_{22}ClNO_4SNa$ ($M + Na^+$) 382.0856; found 382.0857 (TOF MS ES^+).

4-(Butoxymethyl)-8-chloro-2-(2-methoxybenzyl)-1,2-benzoxathiazepine-1,1-dioxide



Colorless oil (133 mg, 74%)

Using general procedure **B**, sultam **9** was produced in 74% (162mg, 0.37 mmol) as an clear oil.

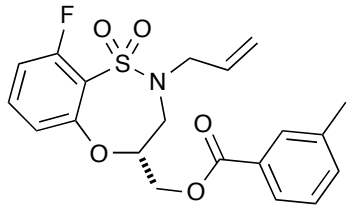
FTIR (neat) 2956, 1463, 1346, 1253, 1166 cm^{-1}:

^{1}H **NMR** (500 MHz, $CDCl_3$) δ = 7.85 (d, *J* = 2.6 Hz, 1H), 7.44 – 7.39 (m, 2H), 7.30 – 7.26 (m, 1H), 7.13 (d, *J* = 8.6 Hz, 1H), 6.96 (td, *J* = 7.5, 1.0 Hz, 1H), 6.86 – 6.82 (m, 1H), 4.40 (d, *J* = 14.7 Hz, 1H), 4.16 (dd, *J* = 5.3, 12.3 Hz, 2H), 3.91 (ddt, *J* = 19.5, 10.0, 5.0 Hz, 1H), 3.75 (s, 3H), 3.65 (dt, *J* = 12.8, 6.4 Hz, 1H), 3.47 (m, 3H), 3.32 – 3.26 (m, 1H), 1.54 (dq, *J* = 12.2, 6.7 Hz, 2H), 1.40 – 1.28 (m, 2H), 0.91 (t, *J* = 7.4 Hz, 3H);

^{13}C **NMR** (125 MHz, $CDCl_3$) δ = 157.3, 153.8, 135.9, 133.9, 130.4, 129.6, 129.4, 128.7, 124.9, 123.3, 120.8, 110.3, 77.5, 71.6, 70.9, 55.2, 50.2, 45.8, 31.7, 19.2, 13.9

HRMS calculated for $C_{21}H_{26}ClNO_5SNa$ ($M + Na^+$) 462.1118; found 462.1106 (TOF MS ES^+).

(*R*)-(2-Allyl-9-fluoro-1,2-benzoxathiazepine-1,1-dioxide)methyl 3-methylbenzoate



clear oil (94%, 114 mg)

FTIR (neat) 1722, 1461, 1355, 1276, 1163 cm^{-1}

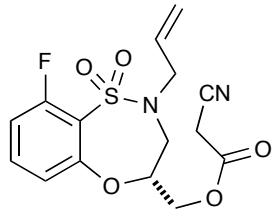
$[\alpha]^{25}_{D}$ = -6.8 (c = 1.5, $CHCl_3$)

^{1}H **NMR** (500 MHz, $CDCl_3$) δ 7.64 – 7.61 (m, 1H), 7.55 (dd, *J* = 2.6, 1.5 Hz 1H), 7.39 – 7.35 (m, 2H), 7.14 (ddd, *J* = 8.3, 2.7, 1.0 Hz, 1H), 6.98 – 6.91 (m, 2H), 5.84 (dddd, *J* = 17.1, 10.1, 7.0, 5.4 Hz, 1H), 5.32 (ddd, *J* = 17.1, 2.7, 1.3 Hz, 1H), 5.28 (dd, *J* = 10.1, 1.2 Hz, 1H), 4.89 (ddt, *J* = 7.6, 6.3, 3.8 Hz, 1H), 4.50 (ddd, *J* = 15.8, 12.1, 5.0 Hz, 2H), 4.04 (dd, *J* = 14.9, 5.3 Hz, 1H), 3.85 (s, 3H), 3.86 – 3.80 (m, 1H), 3.70 – 3.55 (m, 2H);

^{13}C **NMR** (125 MHz, CDCl3) δ 165.8, 160.3 (d, $^{1}J_{C\text{-}F}$ = 257.9 Hz), 159.66, 156.19, 133.7 (d, $^{3}J_{C\text{-}F}$ = 13.2 Hz), 132.4, 130.6, 129.6, 122.8 (d, $^{3}J_{C\text{-}F}$ = 14.4 Hz), 121.9, 119.8, 117.8, 114.3, 112.7 (d, $^{2}J_{C\text{-}F}$ = 23.8 Hz), 80.2, 64.1, 55.4, 53.3, 48.1.

HRMS calculated for $C_{20}H_{20}FNO_6SNa$ ($M + Na^+$) 444.0893; found 444.0883 (TOF MS ES^+)

(*R*)-(2-Allyl-9-fluoro-1,2-benzoxathiazepine-1,1-dioxide)methyl 2-cyanoacetate



Clear Oil (89%, 92.1 mg)

FTIR (neat) 2258, 1746, 1602, 1464, 1160 cm^{-1}

$[\alpha]^{25}_{D}$ = -19.0 (c = 1.4, $CHCl_3$).

^{1}H NMR (500 MHz, $CDCl_3$) δ = 7.41 (td, *J* = 8.3, 5.9 Hz, 1H), 6.99 – 6.95 (m, 2H), 5.81 (dddd, *J* = 17.2, 10.2, 6.9, 5.4 Hz, 1H), 5.31 (dddd, *J* = 17.9, 10.1, 2.6, 1.3 Hz, 2H), 4.77 (ddd, *J* = 14.8, 6.9, 3.6 Hz, 1H), 4.38 (qd, *J* = 12.1, 4.9 Hz, 2H), 4.01 (dd, *J* = 15.0, 5.3 Hz, 1H), 3.79 (dd, *J* = 15.0, 7.0 Hz, 1H), 3.59 (dd, *J* = 14.3, 4.0 Hz, 1H), 3.54 (s, 2H), 3.49 (dd, *J* = 14.3, 11.5 Hz, 1H);

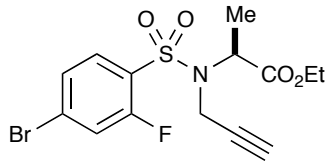
^{13}C NMR (125 MHz, $CDCl_3$) δ = 162.47, 160.0 (d, $^2J_{C\text{-}F}$ = 258.6 Hz), 155.8 (d, $^3J_{C\text{-}F}$ = 3.3 Hz), 133.8 (d, $^2J_{C\text{-}F}$ = 9.4 Hz), 132.24, 122.7 (d, $^2J_{C\text{-}F}$ = 14.7 Hz), 119.83, 117.8 (d, $^3J_{C\text{-}F}$ = 4.3 Hz), 112.9 (d, $^2J_{C\text{-}F}$ = 21.0 Hz), 112.5, 79.4, 65.5, 53.2, 47.8, 24.6;

HRMS calculated for $C_{15}H_{15}FN_2O_5SNa$ (M + Na^+) 377.0583; found 377.0572 (TOF MS ES^+);

Representative Procedure for Intermolecular Mitsunobu Alkylation for Preparation of 3º Sulfonamides

To a flame dried Rb flask under argon containing a stirring solution of 4-bromo-2-fluoro-*N*-(prop-2-ynyl)benzenesulfonamide (0.500 g, 1.716 mmol) in THF (17.6 mL, 0.1M) was added PPh_3 (0.673, 2.567 mmol), and ethyl lactate (0.263 g, 2.225 mmol). After the PPh_3 was completely dissolved, DIAD (0.450g, 2.225mmol) was added drop wise slowly. The reaction was stirred until starting material was completely consumed (by TLC), concentrated under reduced pressure and subjected to flash chromatography to afford (*S*)-ethyl 2-(4-bromo-2-fluoro-*N*-(prop-2-ynyl)phenylsulfonamido)propanoate (0.476 g, 71%) as a clear oil.

(*S*)-ethyl 2-(4-bromo-2-fluoro-*N*-(prop-2-ynyl)phenylsulfonamido)propanoate



Clear oil (476 mg, 71%)

FTIR (neat): 2970, 1730, 2120, 1601, 1578, 1470, 1350, 1161 cm^{-1}

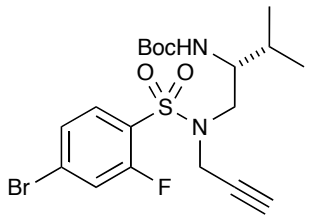
$[\alpha]_D^{20}$ + 63.6 (*c* = 3.0, $CHCl_3$)

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.78 (dd, *J* = 8.3, 7.7 Hz, 1H), 7.42 – 7.35 (m, 2H), 4.80 (q, *J* = 7.4 Hz, 1H), 4.33 (dd, *J* = 18.8, 2.5 Hz, 1H), 4.10 (d, *J* = 2.5 Hz, 1H), 4.08 (d, *J* = 0.4 Hz, 1H), 4.07 (d, *J* = 2.2 Hz, 1H), 2.14 (t, *J* = 2.5 Hz, 1H), 1.60 (d, *J* = 7.2 Hz, 3H), 1.18 (t, *J* = 7.1 Hz, 3H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 171.0, 158.6 ($d_{C\text{-}F}$, *J* = 259.7, Hz), 131.7, 128.3 ($d_{C\text{-}F}$, *J* = 9.3 Hz), 127.5 ($d_{C\text{-}F}$, *J* = 3.7 Hz), 120.6 (d, $J_{C\text{-}F}$ = 24.8 Hz), 78.9, 72.6, 61.6, 55.4, 55.4, 34.3, 16.63, 13.9.

HRMS calculated for $C_{14}H_{15}FBrNO_4SNa$ $(M+Na)^+$ 413.9787; found 413.9785 (EI).

(*R*)-*tert*-butyl-1-(4-bromo-2-fluoro-*N*-(prop-2-ynyl)phenylsulfonamido)-3-methylbutan-2-ylcarbamate



Clear oil (151 mg, 73%)

FTIR (neat): 3360, 2880, 1710, 2350, 1600, 1460, 1325, 1164 cm^{-1}

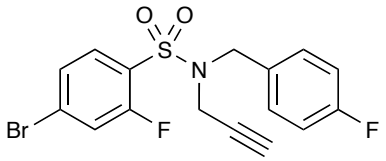
$[\alpha]_D^{20}$ + -16.8 (*c* = 0.85, $CHCl_3$)

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.68 (dd, *J* = 8.3, 7.6 Hz, 1H), 7.32 (ddd, *J* = 11.2, 8.9, 1.7 Hz, 2H), 4.43 (d, *J* = 10.0 Hz, 1H), 4.24 (d, *J* = 19.7 Hz, 1H), 4.07 (dd, *J* = 18.8, 2.3 Hz, 1H), 3.64 (ddd, *J* = 14.9, 10.0, 4.6 Hz, 1H), 3.44 – 3.36 (m, 1H), 3.24 (dd, *J* = 14.1, 4.0 Hz, 1H), 1.96 (t, *J* = 2.3 Hz, 1H), 1.71 (td, *J* = 13.5, 6.8 Hz, 1H), 1.37 (s, 9H), 0.88 (dd, *J* = 17.3, 6.8 Hz, 6H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 159.7, 157.0 (d, $J_{C\text{-}F}$ = 158.0 Hz), 128.3 ($d_{C\text{-}F}$, *J* = 9.1 Hz), 126.9 ($d_{C\text{-}F}$, *J* = 14.8 Hz), 120.7 ($d_{C\text{-}F}$, *J* = 25.0 Hz), 131.9, 127.8, 127.7, 79.4, 75.9, 73.8, 51.9, 48.09, 35.9, 30.4, 28.3, 19.3, 17.6.

HRMS calculated for $C_{19}H_{26}FBrN_2O_4SNa$ $(M+Na)^+$ 499.0678; found 499.0681 (EI).

4-bromo-2-fluoro-*N*-(4-fluorobenzyl)-*N*-(prop-2-ynyl)benzenesulfonamide



Clear oil (152 mg, 91%)

FTIR (neat): 2950, 2325, 1600, 1450, 1357, 1337, 1164 cm^{-1}

1H NMR (500 MHz, $CDCl_3$) δ 7.82 – 7.78 (m, 1H), 7.46 – 7.40 (m, 2H), 7.36 – 7.31 (m, 2H), 7.07 – 7.01 (m, 2H), 4.52 (s, 2H), 3.93 (d, J = 2.4 Hz, 2H), 2.07 (t, J = 2.5 Hz, 1H).

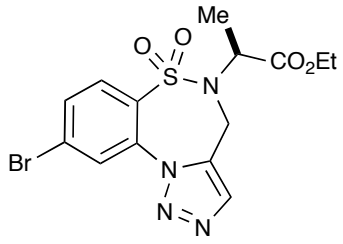
13C **NMR** (125 MHz, CDC_{l3}) δ 162.6 (d, $J_{C\text{-}F}$ = 247.0, Hz), 158.8 (d, $J_{C\text{-}F}$ = 260.2 Hz), 131.99, 130.54, 130.5 (d, $J_{C\text{-}F}$ = 8.3, Hz), 128.5 (d, $J_{C\text{-}F}$ = 9.2 Hz), 127.8 (d, $J_{C\text{-}F}$ = 3.8 Hz), 126.7 (d, $J_{C\text{-}F}$ = 14.7 Hz), 120.7 (d, $J_{C\text{-}F}$ = 24.9 Hz), 115.7 ($d_{C\text{-}F}$, J = 21.6 Hz), 75.6, 74.0, 49.3, 35.4.

HRMS calculated for $C_{16}H_{12}F_2BrNO_4SNa$ $(M+Na)^+$ 421.9638; found 421.9643 (EI).

Representative Procedure for Intramolecular [3 + 2] Cycloaddition

To a flame dried Rb flask charged with (*S*)-ethyl 2-(4-bromo-2-fluoro-*N*-(prop-2-ynyl)phenylsulfonamido)propanoate (0.506 g, 1.338 mmol) was added DMF (3 mL), NaN_3 (0.173 g, 2.676 mmol), 18-crown-6 (0.702 g, 2.676 mmol) and stirred vigorously at 90 ºC for 06 hours. The reaction mixture was cooled down to room temperature followed by extraction with EtOAc (6ml) and H_2O (6 ml). The aqueous layer was subsequently extracted with EtOAc (3 mL X 3) and the combined organic layers were washed with brine, dried over anhydrous Na_2SO_4, concentrated under reduced pressure and subjected to column chromatography (1:1 hexane : EtOAc) to yield the product as a yellow oil (0.309 g, 54 %).

(S)-ethyl 2-(9-bromo-6,6-dioxidobenzo[f][1,2,3]triazolo[5,1-d][1,2,5]thiadiazepin-5(4H)-yl)propanoate



Yellow oil (0.309mg, 54%)

FTIR (neat): 2960, 2115, 1735, 1595, 1569, 1469, 1398, 1334, 1164 cm^{-1}

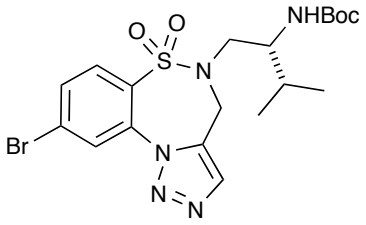
$[\alpha]_D^{20}$ + 35.1 (*c* = 1.6, $CHCl_3$)

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.91 (d, *J* = 8.5 Hz, 1H), 7.83 (d, *J* = 2.2 Hz, 1H), 7.74 (s, 1H), 7.14 (dd, *J* = 8.5, 2.3 Hz, 1H), 4.78 – 4.75 (m, 1H), 4.76 (s, 1H), 4.54 (dd, *J* = 14.6, 0.9 Hz, 1H), 4.01 – 3.96 (m, 2H), 1.53 (d, *J* = 7.4 Hz, 3H), 1.11 (t, *J* = 7.2 Hz, 3H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 170.5, 146.3, 135.1, 133.7, 133.2, 129.4, 128.6, 118.5, 115.1, 61.8, 55.7, 38.1, 16.1, 13.9.

HRMS calculated for $C_{14}H_5BrN_4O_4SNa$ $(M+Na)^+$ 436.9895; found 436.9891 (EI).

(R)-tert-butyl (1-(9-bromo-6,6-dioxidobenzo[f][1,2,3]triazolo[5,1-d][1,2,5]thiadiazepin-5(4H)-yl)-3-methylbutan-2-yl)carbamate



Yellow oil (95mg, 61%)

FTIR (neat): 2960, 1715, 2120, 1605, 1462, 1329, 1164 cm^{-1}

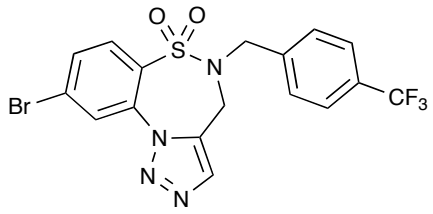
$[\alpha]_D^{20}$ + 13.2 (*c* = 0.65, $CHCl_3$)

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.99 (d, *J* = 8.5 Hz, 1H), 7.95 (d, *J* = 2.2 Hz, 1H), 7.74 (s, 1H), 7.17 (dd, *J* = 8.5, 2.2 Hz, 1H), 4.90 (d, *J* = 15.6 Hz, 1H), 4.49 (dd, *J* = 12.5, 7.8 Hz, 2H), 3.75 – 3.67 (m, 1H), 3.27 (dd, *J* = 13.9, 9.8 Hz, 1H), 2.98 (dd, *J* = 13.9, 5.1 Hz, 1H), 1.78 (td, *J* = 13.5, 6.7 Hz, 1H), 1.42 (s, 9H), 0.94 (d, *J* = 6.8 Hz, 3H), 0.90 (d, *J* = 6.8 Hz, 3H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 156.4, 146.4, 134.4, 134.1, 133.6, 130.0, 127.8, 118.9, 115.1, 79.9, 52.8, 51.8, 41.8, 29.7, 28.3, 19.6, 17.3.

HRMS calculated for $C_{19}H_{26}BrN_5O_4SNa$ $(M+Na)^+$ 522.0787; found 522.0797 (EI).

9-bromo-5-(4-(trifluoromethyl)benzyl)-4,5-dihydrobenzo[f][1,2,3]triazolo[5,1-d][1,2,5]thiadiazepine 6,6-dioxide



Yellow oil (47mg, 73%)

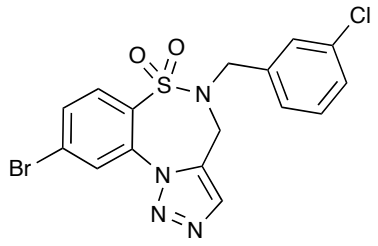
FTIR (neat): 2955, 2128, 1610, 1585, 1465, 1335, 1158 cm^{-1}

^{1}H NMR (500 MHz, $CDCl_3$) δ 8.07 (d, *J* = 8.5 Hz, 1H), 7.97 (d, *J* = 2.2 Hz, 1H), 7.66 (s, 1H), 7.36 – 7.32 (m, 2H), 7.23 – 7.19 (m, 3H), 4.43 (d, *J* = 0.6 Hz, 2H), 4.29 (s, 2H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 134.4, 134.1, 132.9, 132.6, 130.3, 129.9, 127.1, 121.5, 119.0, 115.2, 53.0, 41.4.

HRMS calculated for $C_{17}H_{12}BrF_3N_4O_2SNa$ $(M+Na)^+$ 494.9714; found 494.9710 (EI).

9-bromo-5-(3-chlorobenzyl)-4,5-dihydrobenzo[f][1,2,3]triazolo[5,1-d][1,2,5]thiadiazepine 6,6-dioxide



Yellow oil (55mg, 53%)

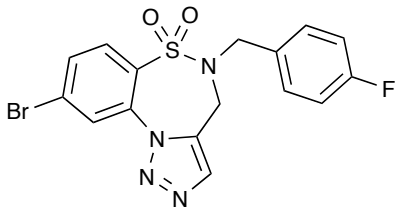
FTIR (neat): 2970, 2122, 1600, 1458, 1340, 1158 cm^{-1}

^{1}H NMR (500 MHz, $CDCl_3$) δ 8.09 (d, *J* = 8.5, 1H), 8.00 (d, *J* = 2.2, 1H), 7.66 (s, 1H), 7.28 (dd, *J* = 8.1, 4.6, 2H), 7.21 (dd, *J* = 8.5, 2.2, 1H), 7.06 (t, *J* = 8.6, 2H), 4.41 (s, 2H), 4.26 (s, 2H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 163.8, 161.8, 146.7, 134.4, 134.1, 133.0, 130.4, 130.2, 129.6, 127.2, 119.0, 116.2, 115.0, 115.1, 53.0, 41.1.

HRMS calculated for $C_{16}H_{12}ClBrN_4O_2SNa$ $(M+Na)^+$ 460.9451; found 460.9461 (EI).

9-bromo-5-(4-fluorobenzyl)-4,5-dihydrobenzo[f][1,2,3]triazolo[5,1-d][1,2,5]thiadiazepine 6,6-dioxide



Yellow oil (42mg, 59%)

FTIR (neat): 2950, 2120, 1595, 1435, 1346, 1159 cm^{-1}

^{1}H NMR (500 MHz, $CDCl_3$) δ 8.08 (d, *J* = 8.5, 1H), 7.96 (d, *J* = 2.2, 1H), 7.67 (s, 1H), 7.34 – 7.27 (m, 3H), 7.24 – 7.16 (m, 2H), 4.43 (d, *J* = 0.6, 2H), 4.28 (s, 2H).

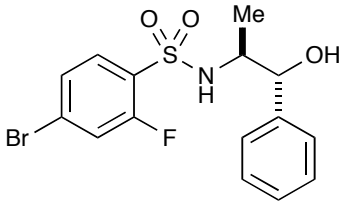
^{13}C NMR (125 MHz, $CDCl_3$) δ 146.8, 135.9, 134.4, 134.1, 133.9 (d, $J_{C\text{-}F}$=267.4 Hz), ,130.3 (d, $J_{C\text{-}F}$ = 4.2 Hz), 128.73 (d, $J_{C\text{-}F}$ = 46.7 Hz), 127.2, 119.0, 115.2, 53.2, 41.4.

HRMS calculated for $C_{16}H_{12}FBrN_4O_2SNa$ $(M+Na)^+$ 444.9746; found 444.9742 (EI).

Representative Procedure for Sulfonylation of Amino alcohols

To a vigorously stirring solution of the norephedrine (1.380g, 7.356 mmol) in CH_2Cl_2 (15 mL 0.4M) and H_2O (7.5 mL 0.8M) in an RB flask was added $NaHCO_3$ (0.927 g, 11.034 mmol). A solution of benzenesulfonyl chloride (1.0 g, 3.678 mmol) in CH_2Cl_2 (3.7 mL) was then added dropwise and the reaction was stirred for 04 – 08 hours. Upon disappearance of sulfonyl chloride, 5 ml 10% HCl was added and reaction was stirred for 05 miniutes. The organic layer was separated and the aqueous layer extracted with CH_2Cl_2 (3 X 5 ml). The combined organic layer was dried over anhydrous sodium sulfate, concentrated under reduced pressure and subject to column chromatography (3:1 hexane : ethyl acetate) to afford the 4-bromo-2-fluoro-*N*-((1*R*,2*S*)-1-hydroxy-1-phenylpropan-2-yl)benzenesulfonamide as a white solid (99%, 2.8g).

4-bromo-2-fluoro-*N*-((1*R*,2*S*)-1-hydroxy-1-phenylpropan-2-yl)benzenesulfonamide



White Solid (2.8g, 99%)

FTIR (neat): 3501, 3310, 2958, 1600, 1450, 1349, 1162 cm^{-1}

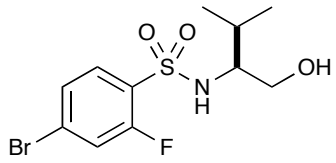
$[\alpha]_D^{20}$ -50.4 (*c* = 0.57 $CHCl_3$)

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.78 (t, *J* = 8.0 Hz, 1H), 7.42 (dd, *J* = 8.4, 1.7 Hz, 1H), 7.37 (dd, *J* = 9.5, 1.7 Hz, 1H), 7.33 (dd, *J* = 11.2, 4.4 Hz, 2H), 7.30 – 7.24 (m, 3H), 5.09 (d, *J* = 8.7 Hz, 1H), 4.81 (t, *J* = 3.6 Hz, 1H), 3.72 – 3.64 (m, 1H), 2.36 (d, *J* = 4.0 Hz,1H) 0.94 (d, *J* = 6.8 Hz, 3H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 158.4 (d, J_{C-F} = 258.7 Hz), 139.9, 130.8, 128.3 (d, J_{C-F}= 13.8 Hz), 128.2 (d, J_{C-F}= 9.1 Hz), 127.9 (d, J_{C-F} = 3.8, Hz), 126.0, 120.8, 120.7 (d, J_{C-F} = 24.3 Hz) 76.0, 55.2, 15.0.

HRMS: Calculated for $C_{15}H_{14}BrFNO_3S$ $(M-H)^+$ 385.9862; Found 385.9864 (EI).

(*S*)-4-bromo-2-fluoro-*N*-(1-hydroxy-3-methylbutan-2-yl)benzenesulfonamide



White Solid (4.60 g, 96%)

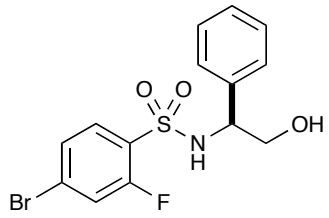
FTIR (neat): 3515, 3596, 2941, 1589, 1469, 1349, 1163 cm^{-1}

$[\alpha]_D^{20}$ + 47.3 (*c* = 1.1, $CHCl_3$)

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.75 (t, *J* = 8.0 Hz, 1H), 7.40 (ddd, *J* = 11.3, 5.7, 1.1 Hz, 2H), 5.46 (d, *J* = 8.7 Hz, 1H), 3.65 – 3.56 (m, 2H), 3.12 (ddd, *J* = 12.0, 7.9, 4.9 Hz, 1H), 2.32 (s, 1H), 0.83 (dd, *J* = 6.8, 2.0 Hz, 6H).

^{13}C NMR (125 MHz, $CDCl_3$) 158.4 (d, *J* = 258.9 Hz), 128.2 (d, *J* = 12.3 Hz), 128.1 (d, *J* = 7.5 Hz), 127.7 (d, *J* = 3.8 Hz), 120.5 (d, *J* = 24.3 Hz), 62.8, 61.4, 29.3, 19.0, 18.4. HRMS calculated for $C_{11}H_{14}FBrNO_3SNa$ $(M-H)^+$ 337.9862; found 337.9858 (EI).

(*S*)-4-bromo-2-fluoro-*N*-(2-hydroxy-1-phenylethyl)benzenesulfonamide



White Solid (3.21 g, 93%)

FTIR (Thin Film): 3490, 3220, 2951, 1598, 1466, 1340, 1164 cm^{-1}

$[\alpha]_D^{20}$ + 6. 9(*c* = 1.0, $CHCl_3$)

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.55 (dd, *J* = 8.3, 7.7, 1H), 7.27 – 7.26 (m, 1H), 7.25 (dd, *J* = 1.8, 0.6, 1H), 7.21 – 7.20 (m, 2H), 7.19 – 7.19 (m, 1H), 7.16 (dd, *J* = 9.4, 1.8, 1H), 7.09 (d, *J* = 1.6, 1H), 7.08 (d, *J* = 2.1, 1H), 5.75 (d, *J* = 7.6, 1H), 4.47 (td, *J* = 7.0, 4.7, 1H), 3.85 – 3.76 (m, 2H), 2.10 – 2.07 (m, 1H).

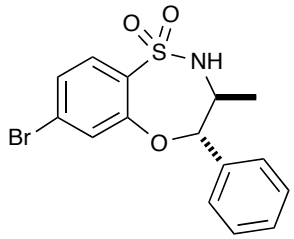
^{13}C NMR (125 MHz, $CDCl_3$) δ 158.2 (d, *J* = 258.8 Hz), 136.8, 130.98, 127.8 (d, *J* = 104.3 Hz) 127.6 (d, *J* = 3.7 Hz), 120.3 (d, *J* = 24.2 Hz), 65.9, 59.8.

HRMS calculated for $C_{14}H_{12}FBrNO_3S$ $(M-H)^+$ 371.9705; found 371.9700 (EI).

Representative Procedure for O-Arylation

To a flame dried MW vial charged with 4-bromo-2-fluoro-*N*-((1*R*,2*S*)-1-hydroxy-1-phenylpropan-2-yl)benzenesulfonamide (0.133 g, 0.3246 mmol) was added DMF (3.2 mL) and Cs_2CO_3 (0.445 g, 1.37 mmol) and the reaction was heated at 140 ºC under MW irradiation for 30 minutes. Upon disappearance of SM, 10 ml $NaHSO_4$ and 15mL Et_2O was added and reaction was stirred for 05 miniutes. The organic layer was separated and the aqueous layer extracted with Et_2O (3 X 5 ml). The combined organic layer was dried over anhydrous sodium sulfate, concentrated under reduced pressure and subject to column chromatography (3:1 hexane : ethyl acetate) to afford the (3S,4S)-7-bromo-3-methyl-4-phenyl-3,4-dihydro-2H-benzo[b][1,4,5]oxathiazepine 1,1-dioxide as a white solid (117 mg. 99%)

(3S,4S)-7-bromo-3-methyl-4-phenyl-3,4-dihydro-2H-benzo[b][1,4,5]oxathiazepine 1,1-dioxide



White Solid (117 mg, 99%)

FTIR (neat): 3210, 2950, 1610, 1595, 1461, 1354, 1337 1164 cm^{-1}

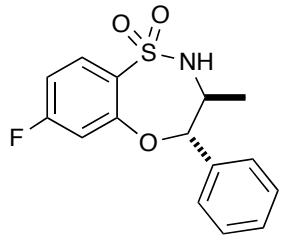
$[\alpha]_D^{20}$ + 97.3 (*c* = 0.65, $CHCl_3$)

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.54 (d, *J* = 8.5 Hz, 1H), 7.35 – 7.32 (m, 1H), 7.32 (d, *J* = 2.0 Hz, 1H), 7.31 – 7.27 (m, 3H), 7.26 – 7.24 (m, 1H), 7.19 (dd, *J* = 8.7, 2.1 Hz, 1H), 5.83 (s, 1H), 5.04 (d, *J* = 5.3 Hz, 1H), 3.93 – 3.85 (m, 1H), 0.99 (d, *J* = 6.8 Hz, 3H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 156.1, 136.4, 128.6, 128.5, 128.1, 126.9, 126.7, 125.3, 125.3, 124.0, 85.2, 55.1, 13.7.

HRMS calculated for $C_{15}H_{13}BrNO_3S$ $(M-H)^+$ 365.9800; found 365.9801(EI).

(3*S*,4*S*)-7-fluoro-3-methyl-4-phenyl-3,4-dihydro-2*H*-benzo[*b*][1,4,5]oxathiazepine 1,1-dioxide



White Solid (1.47 g, 94%)

FTIR (neat): 3200, 2960, 1600, 1585, 1464, 1345, 1335 1164 cm^{-1}

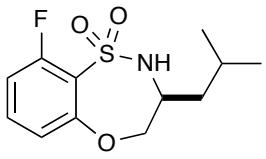
$[\alpha]_D^{20}$ + 108.9 (*c* = 1.14, $CHCl_3$)

1H NMR (500 MHz, $CDCl_3$) δ 7.74 – 7.69 (m, 1H), 7.43 – 7.36 (m, 4H), 7.36 – 7.31 (m, 1H), 6.83 – 6.77 (m, 2H), 5.91 (s, 1H), 5.45 (d, *J* = 5.3, 1H), 4.01 – 3.91 (m, 1H), 1.08 (d, *J* = 6.9, 3H).

13C NMR (125 MHz, $CDCl_3$) δ 164.7 ($d_{c\text{-}F}$, *J* = 254.6 Hz), 157.5 ($d_{c\text{-}F}$, *J* = 12.5 Hz), 129.2 ($d_{c\text{-}F}$, *J* = 10.6 Hz), 111.0 ($d_{c\text{-}F}$, *J* = 22.5Hz), 109.0 ($d_{c\text{-}F}$, *J* = 24.0 Hz) 136.5, 129.2, 125.3, 111.1, 110.9, 85.1, 77.2, 55.0, 13.5.

HRMS calculated for $C_{15}H_{13}BrNO_3SNa$ $(M\text{-}H)^+$ 306.0600; found 306.0608 (EI).

(S)-7-fluoro-3-isobutyl-3,4-dihydro-2H-benzo[b][1,4,5]oxathiazepine-1,1-dioxide



White Solid (1.62 g, 93%)

FTIR (neat): 3210, 2968, 1605, 1588, 1460, 1355, 1345, 1164 cm^{-}

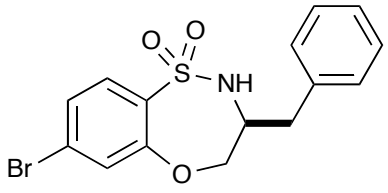
$[\alpha]_D^{20}$**:** + 5.5 (*c* = 1.6, $CHCl_3$)

1H NMR (500 MHz, $CDCl_3$) δ 7.76 – 7.70 (m, 1H), 6.89 – 6.82 (m, 2H), 4.57 (d, *J* = 8.8, 1H), 4.49 (dd, *J* = 12.8, 2.7, 1H), 4.03 – 3.95 (m, 1H), 3.73 (dd, *J* = 12.8, 8.9, 1H), 1.86 (ddq, *J* = 13.2, 8.9, 6.6, 1H), 1.47 – 1.37 (m, 1H), 1.27 (ddd, *J* = 14.0, 9.0, 5.1, 1H), 0.98 (dd, *J* = 6.6, 4.6, 6H).

13C NMR (125 MHz, $CDCl_3$) δ 165.3 (d, $J_{C\text{-}F}$ = 255.3, 1H), 157.6 ($d_{C\text{-}F}$, *J* = 12.2, 1H), 132.7 (d, $J_{C\text{-}F}$ = 3.6, 1H), 129.5 (d, $J_{C\text{-}F}$ = 10.6, 3H), 111.3 ($d_{C\text{-}F}$, *J* = 22.2, 4H), 110.6 (d, $J_{C\text{-}F}$ = 23.5, 3H), 53.9, 39.0, 24.3, 23.0, 21.6.

HRMS calculated for $C_{12}H_{15}FNO_3S$ $(M\text{-}H)^+$ 272.0757; found 272.0760 (EI).

(S)-3-benzyl-7-bromo-3,4-dihydro-2H-benzo[b][1,4,5]oxathiazepine 1,1-dioxide



White Solid (0.990 g, 89%)

FTIR (neat): 3225, 2955, 1610, 1458, 1355, 1158 cm^{-1}

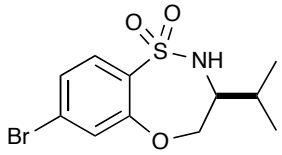
$[\alpha]_D^{20}$ + 3.03 (*c* = 0.82, $CHCl_3$)

1H NMR (500 MHz, $CDCl_3$) δ 7.58 (dt, *J* = 8.8, 1.0 Hz, 1H), 7.34 (ddd, *J* = 7.5, 4.5, 1.3 Hz, 2H), 7.30 (d, *J* = 1.0 Hz, 2H), 7.28 (t, *J* = 2.4 Hz, 1H), 7.22 – 7.19 (m, 2H), 4.73 (d, *J* = 7.9 Hz, 1H), 4.55 (dd, *J* = 12.9, 2.8 Hz, 1H), 4.21 – 4.13 (m, 1H), 3.87 (dd, *J* = 12.9, 8.4 Hz, 1H), 2.98 (dd, *J* = 14.0, 6.9 Hz, 1H), 2.90 – 2.84 (m, 1H).

13C NMR (125 MHz, $CDCl_3$) δ 156.2, 135.4, 134.7, 129.2, 129.1, 129.0, 128.6, 127.4, 127.4, 127.2, 126.1, 76.7, 75.5, 56.1, 36.9.

HRMS calculated for $C_{15}H_{13}BrNO_3S$ $(M-H)^+$ 365.9800; found 365.9804 (EI).

(S)-7-bromo-3-isopropyl-3,4-dihydro-2H-benzo[b][1,4,5]oxathiazepine-1,1-dioxide



White Solid (3.1 g, 87%)

FTIR (neat): 3210, 2960, 1600, 1450, 1350, 1342, 1158 cm^{-1}

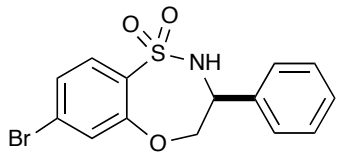
$[\alpha]_D^{20}$ -13.0 (*c* = 1.65, $CHCl_3$)

1H **NMR** (500 MHz, $CDCl_3$) δ 7.50 (d, *J* = 8.4, 1H), 7.31 (t, *J* = 2.0, 1H), 7.25 (d, *J* = 1.9 Hz, 1H), 4.91 (d, *J* = 9.2 Hz, 1H), 4.56 (dd, *J* = 12.6, 2.6 Hz, 1H), 3.82 (dd, *J* = 12.6, 9.1 Hz, 1H), 3.71 (tdd, *J* = 9.1, 6.2, 2.5 Hz 1H), 1.92 (dh, *J* = 13.4, 6.7 Hz, 1H), 1.03 (dd, *J* = 10.3, 6.8 Hz, 6H).

13C **NMR** (125 MHz, $CDCl_3$) δ 156.3, 135.3, 128.5, 127.4, 127.2, 126.5, 60.8, 29.3, 19.4, 18.4.

HRMS calculated for $C_{11}H_{15}BrNO_3S$ $(M+H)^+$ 319.9956; found 319.9958 (EI).

(S)-7-bromo-3-phenyl-3,4-dihydro-2H-benzo[b][1,4,5]oxathiazepine-1,1-dioxide



White Solid (1.45g, 89%)

FTIR (neat): 3220, 2960, 1600, 1585, 1487, 1355, 1164 cm^{-1}

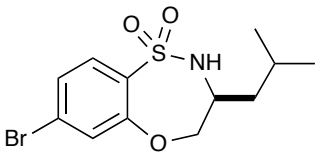
$[\alpha]_D^{20}$ + 23.6 (*c* = 1.0, $CHCl_3$)

^{1}H NMR (500 MHz, $CDCl_3$) 7.67 (d, *J* = 8.4 Hz, 1H), 7.43 – 7.35 (m, 4H), 7.34 (ddd, *J* = 7.2, 3.3, 1.8 Hz, 3H), 5.06 (ddd, *J* = 12.1, 8.5, 5.0 Hz, 2H), 4.69 (dd, *J* = 12.8, 2.7 Hz, 1H), 4.11 (dd, *J* = 12.8, 8.8 Hz, 1H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 155.9, 135.2, 135.1, 129.3, 129.1, 128.4, 127.6, 127.4, 127.0, 126.5, 76.5, 59.2.

HRMS calculated for $C_{14}H_{13}BrNO_3Na$ $(M+H)^+$ 353.9800; found 353.9804 (EI).

(S)-7-bromo-3-isobutyl-3,4-dihydro-2H-benzo[b][1,4,5]oxathiazepine-1,1-dioxide



White Solid (2.32 g, 94%)

FTIR (neat): 3200, 2890, 1607, 1585, 1460, 1335, 1158 cm^{-1}

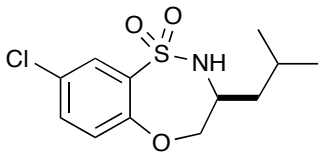
$[\alpha]_D^{20}$ -15.2 (*c* = 1.25, $CHCl_3$)

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.59 (d, *J* = 8.4 Hz, 1H), 7.33 (d, *J* = 1.8 Hz, 1H), 7.30 (dd, *J* = 8.4, 1.9 Hz, 1H), 4.55 (d, *J* = 8.8 Hz, 1H), 4.48 (dd, *J* = 12.8, 2.7 Hz, 1H), 4.03 – 3.95 (m, 1H), 3.71 (dd, *J* = 12.8, 8.9 Hz, 1H), 1.92 – 1.81 (m, 1H), 1.45 – 1.38 (m, 1H), 1.27 (ddd, *J* = 14.0, 9.0, 5.1 Hz, 1H), 0.98 (dd, *J* = 6.6, 4.2 Hz, 6H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 156.3, 135.4, 128.7, 127.5, 127.3, 126.4, 53.9, 39.0, 24.3, 23.0, 21.6.

HRMS calculated for $C_{12}H_{16}BrNO_3SNa$ $(M+Na)^+$ 355.9932; found 355.9930 (EI).

(S)-8-chloro-3-isobutyl-3,4-dihydro-2H-benzo[b][1,4,5]oxathiazepine-1,1-dioxide



White Solid (1.01 g, 91%)

FTIR (neat): 3210, 2900, 1605, 1458, 1345, 1158 cm^{-1}

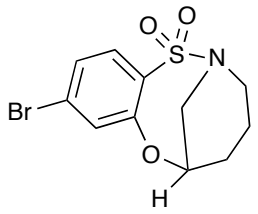
$[\alpha]_D^{20}$ -12.2 (*c* = 0.74, $CHCl_3$)

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.66 (dd, *J* = 7.9, 1.6 Hz, 1H), 7.54 (dd, *J* = 8.0, 1.6 Hz, 1H), 7.11 (t, *J* = 7.9 Hz, 1H), 4.57 (dd, *J* = 12.6, 2.7 Hz, 1H), 4.51 (dd, *J* = 11.6, 7.7 Hz, 1H), 4.14 – 4.05 (m, 1H), 3.64 (dd, *J* = 12.6, 9.5 Hz, 1H), 1.92 – 1.81 (m, 1H), 1.40 (ddd, *J* = 15.1, 9.1, 4.3 Hz, 1H), 1.27 (ddd, *J* = 14.0, 8.9, 5.2 Hz, 1H), 0.98 (dd, *J* = 6.6, 4.7 Hz, 6H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 151.9, 138.6, 134.2, 128.7, 126.0, 124.6, 76.8, 54.3, 38.9, 24.3, 22.9, 21.7.

HRMS calculated for $C_{12}H_{16}ClNO_3SNa$ $(M+Na)^+$ 312.0437; found 312.0437 (EI).

9-bromo-3,4,5,6-tetrahydro-2,6-methanobenzo[*b*][1,4,5]oxathiazonine-1,1-dioxide



White Solid (120 mg, 75%)

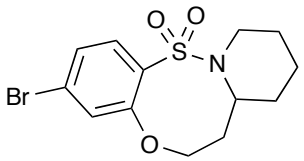
FTIR (neat): 3085, 2880, 1602, 1565, 1355, 1339, 1160 cm^{-1}

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.70 (d, *J* = 8.3 Hz, 1H), 7.37 (t, *J* = 2.5 Hz, 1H), 7.35 (dd, *J* = 8.3, 1.9 Hz, 1H), 4.54 (dd, *J* = 4.4, 2.1 Hz, 1H), 4.40 (ddd, *J* = 15.3, 4.5, 2.3 Hz, 1H), 3.97 – 3.84 (m, 1H), 3.40 (dd, *J* = 15.3, 1.6 Hz, 1H), 3.25 (ddd, *J* = 22.0, 13.8, 7.2 Hz, 1H), 2.19 – 2.09 (m, 1H), 1.93 (dddd, *J* = 15.4, 10.6, 9.1, 4.6 Hz, 1H), 1.22 – 1.14 (m, 2H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 153.7, 136.2, 129.8, 128.1, 127.6, 127.2, 72.2, 51.9, 46.3, 27.4, 16.9.

HRMS calculated for $C_{11}H_{12}BrNO_3SNa$ $(M+Na)^+$ 339.9619; found 339.9622 (EI).

3-bromo-7,7a,8,9,10,11-hexahydro-6H-benzo[b]pyrido[1,2-e][1,4,5]oxathiazocine 13,13-dioxide



White Solid (120mg, 81%)

FTIR (neat): 3067, 2935, 1605, , 1365, 1342, 1163 cm^{-1}

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.72 (d, *J* = 8.3 Hz, 1H), 7.35 (d, *J* = 1.8 Hz, 1H), 7.34 (d, *J* = 1.9 Hz, 1H), 4.62 (dd, *J* = 5.4, 3.1 Hz, 1H), 4.44 (ddd, *J* = 11.4, 10.3, 4.3 Hz, 1H), 4.06 (ddd, *J* = 11.4, 4.9, 4.3 HZ, 1H), 3.65 (d, *J* = 12.2 Hz, 1H), 2.52 (td, *J* = 12.2, 4.1 Hz, 1H), 2.18 (dddd, *J* = 15.4, 10.2, 8.7, 5.1 Hz, 1H), 1.90 (ddd, *J* = 17.0, 9.2, 4.1 Hz, 1H), 1.71 – 1.65 (m, 3H), 1.63 – 1.58 (m, 1H), 3.0 Hz, 1H), 1.50 (dtd, *J* = 15.5, 4.2, 3.0 Hz, 1H), 1.41 (dddd, *J* = 16.3, 12.4, 8.6, 3.7 Hz, 1H).

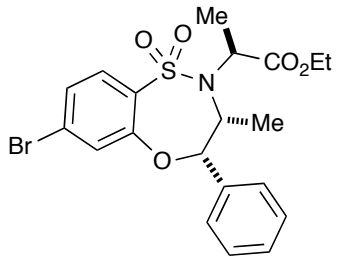
13C **NMR** (125 MHz, $CDCl_3$) δ 156.7, 133.8, 130.9, 127.4, 127.3, 126.9, 75.1, 51.5, 40.7, 31.7, 28.1, 25.5, 18.6.

HRMS calculated for $C_{13}H_{16}BrNO_3SNa$ $(M+Na)^+$ 367.9932; found 367.9929 (EI).

General Prosedure for Intermolecular Mitsunobu Alkylation

To a stirring solution of (3S,4S)-7-bromo-3-methyl-4-phenyl-3,4-dihydro-2H-benzo[b][1,4,5]oxathiazepine 1,1-dioxide (80mg, 0.1901 mmol) in THF (3.8 mL, 0.05M) was added PPh_3 (50 mg, 0.27 mmol), L- ethyl lactate (29 mg, 0.2471mmol) and stirred until all the PPh_3 was fully dissolved. DIAD (54 mg, 0.27 mmol) was then added drop wise slowly and the reaction mixture was stirred until disappearance of starting material. Upon completion of reaction, the solvent was removed under reduced pressure and the crude reaction mixture was subject to chromatography (6:1 hexane : EtOAc) to afford the product as a white solid (58 mg, 77% yield).

(S)-ethyl 2-((3R,4S)-7-bromo-3-methyl-1,1-dioxido-4-phenyl-3,4-dihydro-2H-benzo[b][1,4,5]oxathiazepin-2-yl)propanoate



White Solid (58 mg, 77%)

FTIR (neat): 2950, 1603, 1460, 1349, 1158 cm^{-1}

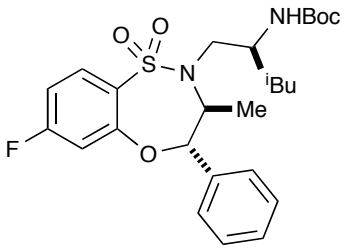
$[\alpha]_D^{20}$ - 35.6 (*c* = 1.75, $CHCl_3$)

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.73 (t, *J* = 5.1 Hz, 1H), 7.42 – 7.39 (m, 5H), 7.38 – 7.37 (m, 1H), 7.33 (ddd, *J* = 7.0, 5.6, 2.6 Hz, 1H), 5.11 (d, *J* = 2.1 Hz, 1H), 5.10 – 5.07 (m, 1H), 4.03 (dq, *J* = 10.9, 7.2 Hz, 1H), 3.92 (dq, *J* = 10.9, 7.1 Hz, 1H), 3.76 (qd, *J* = 7.2, 2.3 Hz, 1H), 1.54 (d, *J* = 7.2 Hz, 3H), 1.39 (d, *J* = 7.2 Hz, 3H), 0.96 (t, *J* = 7.2 Hz, 3H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 171.4, 156.5, 138.3, 136.6, 128.5, 128.1, 127.9, 127.5, 126.6, 125.4, 85.6, 61.4, 57.7, 56.7, 16.8, 15.4, 13.6.

HRMS calculated for $C_{20}H_{22}BrNO_5SNa$ $(M+Na)^+$ 490.0300; found 490.0301 (EI).

tert-butyl ((S)-1-((3S,4S)-7-fluoro-3-methyl-1,1-dioxido-4-phenyl-3,4-dihydro-2H-benzo[b][1,4,5]oxathiazepin-2-yl)-4-methylpentan-2-yl)carbamate



White Solid (76 mg, 73%)

FTIR (Thin Film): 3230, 3010, 2974, 2321, 1610, 1584, 1476, 1335, 1251, 1164 cm^{-1}

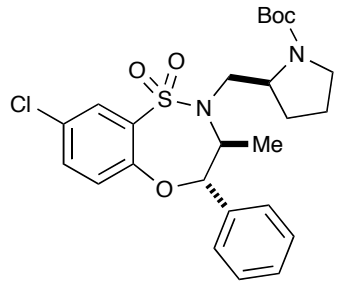
$[\alpha]_D^{20}$ -25.2 (*c* = 2.25, $CHCl_3$)

1H NMR (500 MHz, $CDCl_3$) δ 7.86 (dd, *J* = 8.7, 6.2 Hz, 1H), 7.40 (ddd, *J* = 14.7, 8.0, 4.2 Hz, 4H), 7.36 – 7.31 (m, 1H), 6.98 – 6.91 (m, 2H), 5.01 (s, 1H), 4.59 (d, *J* = 8.5 Hz, 1H), 3.94 – 3.84 (m, 1H), 3.61 (qd, *J* = 7.2, 2.0 Hz, 1H), 3.33 (dd, *J* = 14.5, 8.4 Hz, 1H), 3.05 (dd, *J* = 14.5, 4.0 Hz, 1H), 1.77 – 1.68 (m, 1H), 1.42 (s, 9H), 1.41 (d, 6.7 Hz, 3H), 1.38 (s, 1H), 1.34 – 1.24 (m, 2H), 0.94 (t, *J* = 6.9 Hz, 6H).

13C NMR (125 MHz, $CDCl_3$) δ 166.5, 164.4, 158.0, 157.9, 155.9, 137.8, 131.9, 131.9, 130.4, 130.3, 128.6, 128.5, 128.1, 127.9, 125.3, 125.3, 125.2, 111.9, 111.7, 111.4, 111.3, 83.0, 79.4, 63.2, 53.9, 47.6, 41.9, 28.4, 27.7, 24.8, 23.0, 22.1, 14.0.

HRMS calculated for $C_{26}H_{35}ClN_2O_5SNa$ $(M+Na)^+$ 529.2148; found 529.2143 (EI).

(S)-tert-butyl 2-(((3S,4S)-8-chloro-3-methyl-1,1-dioxido-4-phenyl-3,4-dihydro-2H-benzo[b][1,4,5]oxathiazepin-2-yl)methyl)pyrrolidine-1-carboxylate



White Solid (132 mg, 67%)

FTIR (Thin Film): 3050, 2980, 2261, 1610, 1585, 1335, 1164 cm^{-1}

$[\alpha]_D^{20}$ - 42.3 (*c* = 3.0, $CHCl_3$)

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.80 (s, 1H), 7.46 – 7.35 (m, 6H), 7.31 (d, *J* = 8.8, 1H), 6.92 (t, *J* = 12.0, 1H), 5.52 (m, 1H), 3.94 (d, *J* = 30.8, 2H), 3.36 (d, *J* = 7.9, 3H), 2.13 (m, 1H), 1.95 (d, *J* = 7.5, 1H), 1.89 (m, 1H), 1.79 (m, 2H), 1.42 (s, 9H), 1.17 (d, *J* = 6.8 Hz, 3H).

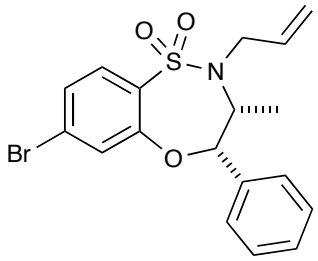
^{13}C NMR (125 MHz, $CDCl_3$) δ 154.9, 153.9, 137.77, 133.3, 129.1, 128.9, 128.8, 128.6, 128.0, 127.2, 126.95, 79.5, 79.4, 57.1, 56.5, 47.5, 46.8, 28.4, 23.8, 22.7, 17.3.

HRMS calculated for $C_{25}H_{31}ClN_2O_5SNa$ $(M+Na)^+$ 529.1540; found 529.1543 (EI).

Representative Procedure for Allylation / Benzylation

To a stirring solution of the (3*S*,4*S*)-7-bromo-3-methyl-4-phenyl-3,4-dihydro-2*H*-benzo[*b*][1,4,5]oxathiazepine 1,1-dioxide (82mg, 0.2227 mmol) in CH_3CN (2.2mL, 0.1M) and anhydrous K_2CO_3 (93mg, 0.668 mmol) was added allyl bromide (54 mg, 0.4454 mmol) and the reaction was stirred at 60 ºC until disappearance of starting material. The reaction mixture was then filtered through a silica pad and solvent was removed under reduced pressure. The crude product was subjected to flash chromatography (6:1 hexane : EtOAc) to afford the allylated product as a white solid (77 mg, 89% yield).

(3R,4S)-2-allyl-7-bromo-3-methyl-4-phenyl-3,4-dihydro-2H-benzo[b][1,4,5]oxathiazepine 1,1-dioxide



White Solid (77 mg, 89%)

FTIR (thin film): 3040, 2980, 1635, 1605, 1584, 1480, 1350, 1164 cm^{-1}

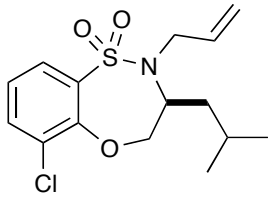
$[\alpha]_D^{20}$ + 70.43 (*c* = 1.15, $CHCl_3$)

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.70 (d, *J* = 8.5 Hz, 1H), 7.42 (ddd, *J* = 10.7, 6.0, 2.8 Hz, 3H), 7.39 – 7.36 (m, 2H), 7.30 (dd, *J* = 8.5, 1.9 Hz, 1H), 7.20 (d, *J* = 1.9 Hz, 1H), 5.86 (dddd, *J* = 17.4, 10.1, 7.5, 5.2 Hz, 1H), 5.60 (s, 1H), 5.35 (dd, *J* = 17.1, 1.5 Hz, 1H), 5.25 (dd, *J* = 10.1, 1.0 Hz, 1H), 4.06 (d, *J* = 10.6 Hz, 1H), 3.86 (s, 1H), 3.77 (dd, *J* = 15.2, 7.5 Hz, 1H), 1.16 (d, *J* = 6.9 Hz, 3H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 155.6, 137.7, 133.1, 131.0, 129.5, 129.1, 128.9, 128.9, 128.8, 127.0, 126.7, 125.1, 119.3, 88.9, 77.2, 62.0, 53.9, 53.9, 17.6.

HRMS calculated for $C_{18}H_{18}BrNO_3SNa$ $(M+Na)^+$ 430.0088; found 430.0084 (EI).

(S)-2-allyl-6-chloro-3-isobutyl-3,4-dihydro-2H-benzo[b][1,4,5]oxathiazepine-1,1-dioxide



White Solid (114 mg, 86%)

FTIR (thin film): 3054, 2320, 1645, 1600, 1480, 1356, 1161 cm^{-1}

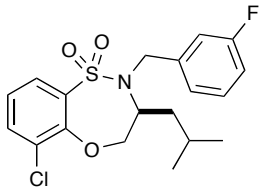
$[\alpha]_D^{20}$ + 88.5 (*c* = 1.1, $CHCl_3$)

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.73 (dd, *J* = 7.9 Hz, 1.6, 1H), 7.53 (dd, *J* = 7.9, 1.6 Hz, 1H), 7.11 (t, *J* = 7.9 Hz, 1H), 5.87 – 5.75 (m, 1H), 5.23 (ddd, *J* = 17.1, 2.7, 1.3 Hz, 1H), 5.17 (dd, *J* = 10.1, 1.2 Hz, 1H), 4.42 (d, *J* = 4.9 Hz, 2H), 4.04 (s, 1H), 3.78 (dd, *J* = 15.4, 5.5, Hz 1H), 3.62 (dd, *J* = 15.5, 7.0 Hz, 1H), 1.76 (dq, *J* = 12.4, 6.4 Hz, 2H), 1.32 (dd, *J* = 13.2, 6.9 Hz, 1H), 0.95 (dd, *J* = 6.5, 2.4 Hz, 6H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 151.5, 134.1, 133.5, 127.6, 123.8, 118.9, 74.3, 59.3, 39.0, 24.6, 22.6, 22.3.

HRMS calculated for $C_{15}H_{20}ClNO_3SNa$ $(M+Na)^+$ 352.0750; found 352.0740. (EI).

(S)-6-chloro-2-(3-fluorobenzyl)-3-isobutyl-3,4-dihydro-2H-benzo[b][1,4,5]oxathiazepine 1,1-dioxide



White Solid (68 mg, 83%)

FTIR (Thin Film): 3060, 2980, 2334,1598, 1345, 1164 cm^{-1}

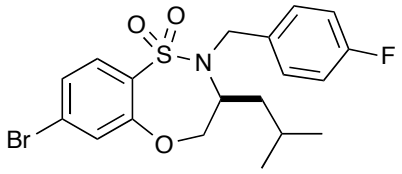
$[\alpha]_D^{20}$ -66.7 ($c = 0.38$, $CHCl_3$)

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.77 (dd, J = 7.9, 1.6 Hz, 1H), 7.55 (dd, J = 7.9, 1.6 Hz, 1H), 7.33 – 7.26 (m, 1H), 7.13 (dd, J = 16.0, 8.1 Hz, 3H), 6.99 (td, J = 8.4, 1.9 Hz, 1H), 4.48 (d, J = 25.3 Hz, 2H), 4.32 (s, 1H), 4.11 (d, J = 15.3 Hz, 1H), 3.98 (s, 1H), 1.40 (dd, J = 13.3, 6.7 Hz, 1H), 1.28 (dd, J = 14.1, 7.1 Hz, 2H), 0.68 (dd, J = 8.7, 6.6 Hz, 6H).

^{13}C NMR (125 MHz, $CDCl_3$) δ162.8, (d, $J_{C\text{-}F}$ = 246.8,) 151.5, (d, $J_{C\text{-}F}$ = 7.5), 138.7 134.2 (d, $J_{C\text{-}F}$ = 11.4), 130.1 (d, $J_{C\text{-}F}$ = 8.2), 130.0, 127.5 (d $J_{C\text{-}F}$ = 43.5), 124.5, 124.2 (d, $J_{C\text{-}F}$ = 2.6 Hz), 123.9, 115.5 (t, $J_{C\text{-}F}$ = 23.0), 115.0 (d, $J_{C\text{-}F}$ = 21.1), 74.1, 59.9, 39.3, 24.8, 22.2, 22.1.

HRMS: Calculated for $C_{19}H_{21}ClFNNaO_3S$ $(M+Na)^+$ 420.0812; found 420.0816

(S)-7-bromo-2-(4-fluorobenzyl)-3-isobutyl-3,4-dihydro-2H-benzo[b][1,4,5]oxathiazepine 1,1-dioxide



White Solid (77 mg, 81%)

FTIR (Thin Film): 3045, 2970, 1605, 1365, 1335, 1164 cm^{-1}

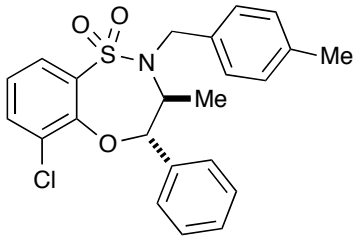
$[\alpha]_D^{20}$ + 40.3 (*c* = 2.25, $CHCl_3$)

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.70 (d, *J* = 8.4 Hz, 1H), 7.36 – 7.30 (m, 3H), 7.23 (d, *J* = 1.8 Hz, 1H), 7.04 – 6.98 (m, 2H), 4.60 (t, *J* = 11.9 Hz, 1H), 4.39 (d, *J* = 14.7v, 1H), 4.31 (dd, *J* = 13.2, 4.5 Hz, 1H), 4.05 (d, *J* = 14.8 Hz, 1H), 3.81 (s, 1H), 1.55 (d, *J* = 8.5 Hz, 2H), 1.34 (td, *J* = 13.3, 6.6 Hz, 1H), 1.29 – 1.22 (m, 1H), 0.65 (dd, *J* = 18.7, 6.5 Hz, 6H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 162.6 (d, $J_{C\text{-}F}$ = 246.8 Hz), 156.1, 131.7 (d, $J_{C\text{-}F}$ = 3.1 Hz), 131.1, 130.6 (d, $J_{C\text{-}F}$ = 8.2 Hz), 130.2 127.3 126.7, 124.9, 115.4 (d, $J_{C\text{-}F}$ = 21.5 Hz) 74.4, 59.6, 39.5, 30.9, 24.7, 22.3, 22.1.

HRMS calculated for $C_{19}H_{21}BrFNO_3SNa$ $(M+Na)^+$ 464.0307: found 464.0308.

(3S,4S)-6-chloro-3-methyl-2-(4-methylbenzyl)-4-phenyl-3,4-dihydro-2H-benzo[b][1,4,5]oxathiazepine 1,1-dioxide



White Solid (58 mg, 74%)

FTIR (Thin Film): 3045, 2868, 2323, 1605, 1594, 1350, 1154 cm^{-1}

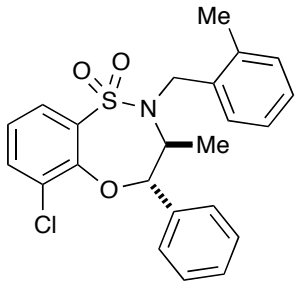
$[\alpha]_D^{20}$ + 109.8 (*c* = 2.4, $CHCl_3$)

1H NMR (500 MHz, $CDCl_3$) δ 7.86 (dd, *J* = 7.8, 1.6 Hz, 1H), 7.58 (dd, *J* = 8.0, 1.6 Hz, 1H), 7.37 (d, *J* = 4.4 Hz, 4H), 7.32 – 7.27 (m, 3H), 7.23 (t, *J* = 7.9 Hz, 1H), 7.18 (d, *J* = 7.8 Hz, 2H), 5.02 (d, *J* = 1.6 Hz, 1H), 4.81 (d, *J* = 14.8 Hz, 1H), 4.03 (d, *J* = 14.8 Hz, 1H), 3.55 (qd, *J* = 7.2, 2.2 Hz, 1H), 2.35 (s, 3H), 1.30 (d, *J* = 7.3 Hz, 3H).

13C NMR (125 MHz, $CDCl_3$) δ 152.4, 138.1, 137.6, 137.4, 134.5, 132.8, 129.6, 129.4, 128.4, 128.2, 127.6, 126.9, 125.2, 125.1, 82.1, 60.9, 53.6, 21.1, 14.4.

HRMS calculated for $C_{23}H_{22}ClNO_3SNa$ $(M+Na)^+$ 450.0907; found 450.0905 (EI).

(3S,4S)-6-chloro-3-methyl-2-(2-methylbenzyl)-4-phenyl-3,4-dihydro-2H-benzo[b][1,4,5]oxathiazepine 1,1-dioxide



White Solid (56 mg, 73%)

FTIR (Thin Film): 2970, 2890, 2300, 1610, 1595, 1360, 1345, 1160 cm^{-1}

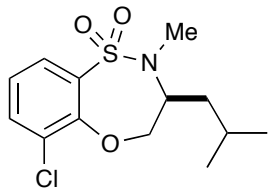
$[\alpha]_D^{20}$ + 54.3 (*c* = 2.8, $CHCl_3$)

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.87 (dd, *J* = 7.8, 1.6 Hz, 1H), 7.60 (dd, *J* = 8.0, 1.6 Hz, 1H), 7.40 – 7.34 (m, 5H), 7.32 – 7.22 (m, 6H), 4.92 (d, *J* = 14.7 Hz, 1H), 3.99 (d, *J* = 14.7 Hz, 1H), 3.49 (qd, *J* = 7.2, 2.1 Hz, 1H), 2.44 (s, 3H), 1.31 (d, *J* = 7.3 Hz, 3H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 152.5, 137.6, 137.2, 136.8, 134.6, 133.2, 131.1, 129.5, 129.2, 128.4, 128.4, 127.6, 127.3, 126.3, 125.2, 81.6, 60.2, 51.7, 19.4, 14.3.

HRMS calculated for $C_{23}H_{22}ClNO_3SNa$ $(M+Na)^+$ 450.0907; found 450.0909 (EI).

(S)-6-chloro-3-isobutyl-2-methyl-3,4-dihydro-2H-benzo[b][1,4,5]oxathiazepine 1,1-dioxide



White Solid (55 mg, 73%)

FTIR (Thin Film): 3050, 2873, 2321, 1610, 1370, 1345, 1154 cm^{-1}

$[\alpha]_D^{20}$ + 8.9 (*c* = 0.78, $CHCl_3$)

1H NMR (**500 MHz,** $CDCl_3$) δ 37.74 (dd, *J* = 7.9, 1.6 Hz, 1H), 7.57 (dd, *J* = 8.0, 1.6 Hz, 1H), 7.17 (t, *J* = 7.9 Hz, 1H), 4.45 (s, 1H), 4.29 (dd, *J* = 13.0, 2.7 Hz, 1H), (m, 1H), 2.61 (s, 3H), 1.79 (ddd, *J* = 11.5, 10.4, 6.6 Hz, 1H), 1.49 (s, 1H), 1.19 (ddd, *J* = 14.4, 9.3, 5.3 Hz, 1H), 1.01 (dd, *J* = 11.4, 6.6 Hz, 6H).

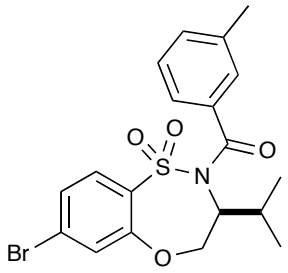
13C NMR (125 MHz, $CDCl_3$) δ 151.5, 134.5, 134.4, 134.3, 128.4, 124.6, 77.5 70.7, 58.4, 36.5, 24.2, 23.2, 21.6.

HRMS calculated for $C_{13}H_{18}ClNO_3SNa$ $(M+Na)^+$ 326.0594; found 326.0597 (EI).

Representative Procedure for Acylation

A flame dried Rb flask under Ar was charged with (S)-7-bromo-3-isopropyl-3,4-dihydro-2H-benzo[b][1,4,5]oxathiazepine 1,1-dioxide (89 mg, 0.2417 mmol) and added CH_2Cl_2 (0.5 mL), Et_3N (26.9 mg, 0.2658 mmol) and DMAP (3 mg, 0.024 mmol). The reaction mixture was cooled in an ice bath and 3-methyl benzoyl chloride (49 mg, 0.29 mmol) was added slowly dropwise. The reaction mixture was allowed to warm to room temperature and stirred until disappearance of starting material. The reaction mixture was then filtered through a silica pad and solvent was removed under reduced pressure. The crude product was subjected to flash chromatography (6:1 hexane : EtOAc) to afford the acylated product (S)-(7-bromo-3-isopropyl-1,1-dioxido-3,4-dihydro-2Hbenzo[b][1,4,5]oxathiazepin-2-yl)(m-tolyl)methanone as a white solid (76 mg, 73% yield).

(S)-(7-bromo-3-isopropyl-1,1-dioxido-3,4-dihydro-2H-benzo[b][1,4,5]oxathiazepin-2-yl)(m-tolyl)methanone



White Solid (76 mg, 73%)

FTIR (Thin Film): 3050, 2980, 2355, 1698, 1610, 1597, 1369, 1357, 1170 cm^{-1}

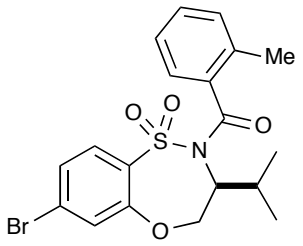
$[\alpha]_D^{20}$ + 10.3 (*c* = 0.8, $CHCl_3$)

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.50 (d, *J* = 8.5 Hz, 1H), 7.35 (d, *J* = 1.9 Hz, 1H), 7.29 (dd, *J* = 8.5, 1.9 Hz, 1H), 7.22 (t, *J* = 8.0 Hz, 1H), 7.00 (ddd, *J* = 8.3, 2.6, 0.8 Hz, 1H), 6.93 (d, *J* = 7.5 Hz, 1H), 6.84 (s, 1H), 4.85 (dd, *J* = 12.8, 10.7 Hz, 1H), 4.60 (dd, *J* = 12.8, 5.1 Hz, 1H), 4.53 (td, *J* = 10.4, 5.1 Hz, 1H), 3.70 (s, 3H), 2.39 (ddt, *J* = 13.4, 10.1, 6.7 Hz, 1H), 1.19 (d, *J* = 6.7 Hz, 3H), 1.04 (d, *J* = 6.7 Hz, 3H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 172.1, 159.1, 156.2, 136.8, 131.6, 129.02 128.9, 128.4, 126.7, 125.3, 120.3, 118.1, 112.6, 73.8, 66.4, 55.2, 28.9, 20.6, 20.5.

HRMS calculated for $C_{19}H_{20}BrNO_4SNa$ $(M+Na)^+$ 460.0194; found 460.0197 (EI).

(S)-(7-bromo-3-isopropyl-1,1-dioxido-3,4-dihydro-2H-benzo[b][1,4,5]oxathiazepin-2-yl)(o-tolyl)methanone



White Solid (64 mg, 80%)

FTIR (neat): 2950, 2340, 1695, 1603, 1460, 1349, 1160 cm^{-1}

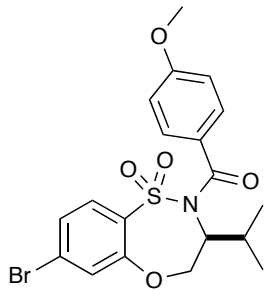
$[\alpha]_D^{20}$ + -31.9 (*c* = 0.28, $CHCl_3$)

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.36 (d, *J* = 8.5, 1H), 7.33 – 7.29 (m, 2H), 7.20 (dd, *J* = 8.5, 1.9, 1H), 6.82 (s, 2H), 6.74 (d, *J* = 8.4, 1H), 5.10 (d, *J* = 5.5, 1H), 4.88 (dd, *J* = 13.0, 11.6, 1H), 4.67 (dd, *J* = 13.0, 5.7 Hz, 1H), 3.41 (s, 3H), 2.37 (qd, *J* = 13.4, 6.7 Hz, 1H), 1.17 (d, *J* = 6.8 Hz, 3H), 1.07 (d, *J* = 6.7 Hz, 3H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 169.7, 156.7, 131.0, 130.9, 128.5, 127.9, 126.8, 126.2, 125.6, 124.6, 119.9, 110.1, 73.5, 64.1, 54.9, 29.1, 20.5, 19.8.

HRMS calculated for $C_{19}H_{20}BrNO_4SNa$ $(M+Na)^+$ 460.0194; found 460.0193 (EI).

(S)-(7-bromo-3-isopropyl-1,1-dioxido-3,4-dihydro-2H-benzo[b][1,4,5]oxathiazepin-2-yl)(3-methoxyphenyl)methanone



White Solid (59mg, 77%)

FTIR (Thin Film): 3065, 2861, 2350, 1690, 1605, 1165 cm^{-1}

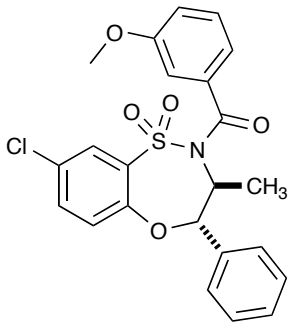
$[\alpha]_D^{20}$ + 48.1 (*c* = 0.56, $CHCl_3$)

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.64 (d, *J* = 8.8, 2H), 7.51 (d, *J* = 8.5 Hz, 1H), 7.34 (d, *J* = 1.9 Hz, 1H), 7.30 – 7.26 (m, 1H), 6.90 – 6.84 (m, 2H), 4.87 (dd, *J* = 13.0, 10.0 Hz, 1H), 4.55 (dd, *J* = 13.0, 4.3 Hz, 1H), 4.36 (td, *J* = 10.0, 4.2 Hz, 1H), 3.85 (s, 3H), 2.37 (qd, *J* = 13.3, 6.7 Hz, 1H), 1.16 (d, *J* = 6.7 Hz, 3H), 1.05 (d, *J* = 6.7 Hz, 3H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 172.0, 163.4, 156.2, 132.1, 132.1, 129.20 128.4, 127.4, 126.9, 125.7, 113.3, 73.5, 67.0, 55.4, 28.7, 20.7, 20.6.

HRMS calculated for $C_{19}H_{20}BrNNaO_5S$ $(M+Na)^+$ 476.0143; Found 476.0140

((3S,4S)-8-chloro-3-methyl-1,1-dioxido-4-phenyl-3,4-dihydro-2H-benzo[b][1,4,5]oxathiazepin-2-yl)(3-methoxyphenyl)methanone



White Solid (54 mg, 81%)

FTIR (Thin Film): 3080, 2975, 2341, 1697, 1579, 1396, 1170 cm^{-1}

$[\alpha]_D^{20}$ + 23.1 (*c* = 0.48, $CHCl_3$)

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.68 (d, *J* = 8.5 Hz, 1H), 7.42 – 7.38 (m, 3H), 7.37 (dd, *J* = 8.5, 1.9 Hz, 1H), 7.34 (dd, *J* = 6.7, 3.0 Hz, 2H), 7.29 (q, *J* = 7.1 Hz, 2H), 7.11 – 7.00 (m, 3H), 5.78 (d, *J* = 10.8 Hz, 1H), 4.60 (dd, *J* = 10.8, 6.7 Hz, 1H), 3.73 (s, 3H), 1.44 (d, *J* = 6.3 Hz, 3H).

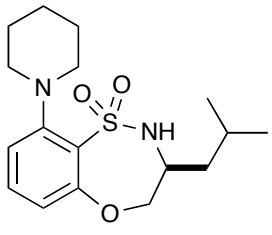
^{13}C NMR (125 MHz, $CDCl_3$) δ 172.2, 159.5, 155.5, 136.9, 135.8, 129.6, 129.4, 128.9, 128.2, 128.0, 127.2, 126.9, 125.4, 120.3, 120.3, 119.0, 112.5, 63.5, 55.2, 16.6.

HRMS calculated for $C_{23}H_{20}ClNNaO_5S$ $(M+Na)^+$ 480.0648; Found 480.0649

Representative Procedure for Intermolecular S_NAr Addition

To a flame dried microwave vial was added (S)-7-fluoro-3-isobutyl-3,4-dihydro-2H-benzo[b][1,4,5]oxathiazepine 1,1-dioxide (0.600 mg, 2.195 mmol), piperidine (0.468 g, 6.585 mmol) and DMSO (2.2 mL). The *m*W vial was quickly sealed and stirred at 140 ºC for 30 minutes under *m*W irradiation. The reaction was allowed to cool down and Et_2O (3 ml), EtOAc (1 ml) and H_2O (3 ml) was added to the reaction mixture and stirred for 10 minutes. The aqueous layer was extracted with Et_2O (1 ml X 4), and the combined organic layers were dried over anhydrous Na_2SO_4, concentrated under reduced pressure and subject to column chromatography (6:1 hexane : EtOAc) to afford (S)-3-isobutyl-9-(piperidin-1-yl)-3,4-dihydro-2H-benzo[b][1,4,5]oxathiazepine 1,1-dioxide (571 mg, 77%) as a clear oil.

(S)-3-isobutyl-9-(piperidin-1-yl)-3,4-dihydro-2H-benzo[b][1,4,5]oxathiazepine 1,1-dioxide



Pale Yellow Oil (571 mg, 77%)

FTIR (neat): 3257, 2933, 1599, 1460, 1380, 1354, 1149 cm^{-1}

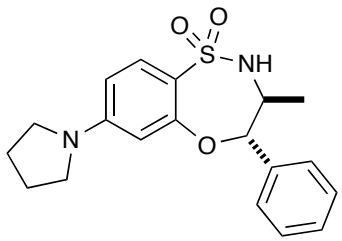
$[\alpha]_D^{20}$ - 38.6 (*c* = 0.89, $CHCl_3$)

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.29 – 7.24 (m, 1H), 6.92 (dd, *J* = 8.0, 1.1, 1H), 6.75 (dd, *J* = 8.2, 1.1, 1H), 4.80 (d, *J* = 7.9, 1H), 4.39 (dd, *J* = 12.4, 4.9, 1H), 4.06 (dd, *J* = 12.4, 5.9, 1H), 3.80 – 3.71 (m, 1H), 3.02 (s, 2H), 2.92 (t, *J* = 18.6, 2H), 1.91 – 1.81 (m, 1H), 1.81 – 1.70 (m, 4H), 1.70 – 1.61 (m, 1H), 1.55 (s, 2H), 1.32 (ddd, *J* = 14.0, 8.4, 5.7, 1H), 0.97 (d, *J* = 6.6, 6H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 158.4, 155.5, 132.5, 130.5, 117.7, 116.5, 75.9, 55.0, 52.6, 40.1, 25.9, 24.4, 24.2, 22.9, 21.8.

HRMS calculated for $C_{17}H_{26}N2NaO_3S$ $(M+Na)^+$ 361.1562; Found 361.1566

(3*S*,4*S*)-3-methyl-4-phenyl-7-(pyrrolidin-1-yl)-3,4-dihydro-2*H*-benzo[*b*][1,4,5]oxathiazepine 1,1-dioxide



Pale Yellow Solid (303 mg, 79%)

FTIR (neat): 3261, 2970, 2358, 1583, 1560, 1380, 1299, 1164 cm^{-1}

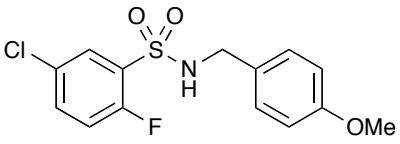
$[\alpha]_D^{20}$ + 3.59 (*c* = 1.72, $CHCl_3$)

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.42 – 7.38 (m, 4H), 7.34 – 7.27 (m, 1H), 7.16 – 7.10 (m, 1H), 6.59 – 6.51 (m, 2H), 6.02 (s, 1H), 4.62 (d, *J* = 7.2 Hz, 1H), 4.19 – 4.01 (m, 1H), 3.70 (dd, *J* = 15.9, 9.7 Hz, 2H), 3.47 (dd, *J* = 10.4, 6.6 Hz, 2H), 2.11 – 1.97 (m, 2H), 1.97 – 1.83 (m, 2H), 0.99 (dd, *J* = 21.0, 6.8 Hz, 3H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 159.4, 150.3, 137.4, 132.2, 129.0, 128.5, 128.2, 127.6, 125.1, 110.5, 108.5, 83.3, 55.2, 52.7, 25.9, 13.6.

HRMS calculated for $C_{19}H_{22}N_2NaO_3S$ $(M+Na)^+$ 381.1249; Found 381.1250

Appendix A
^{1}H, ^{13}C NMR Spectra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Cl
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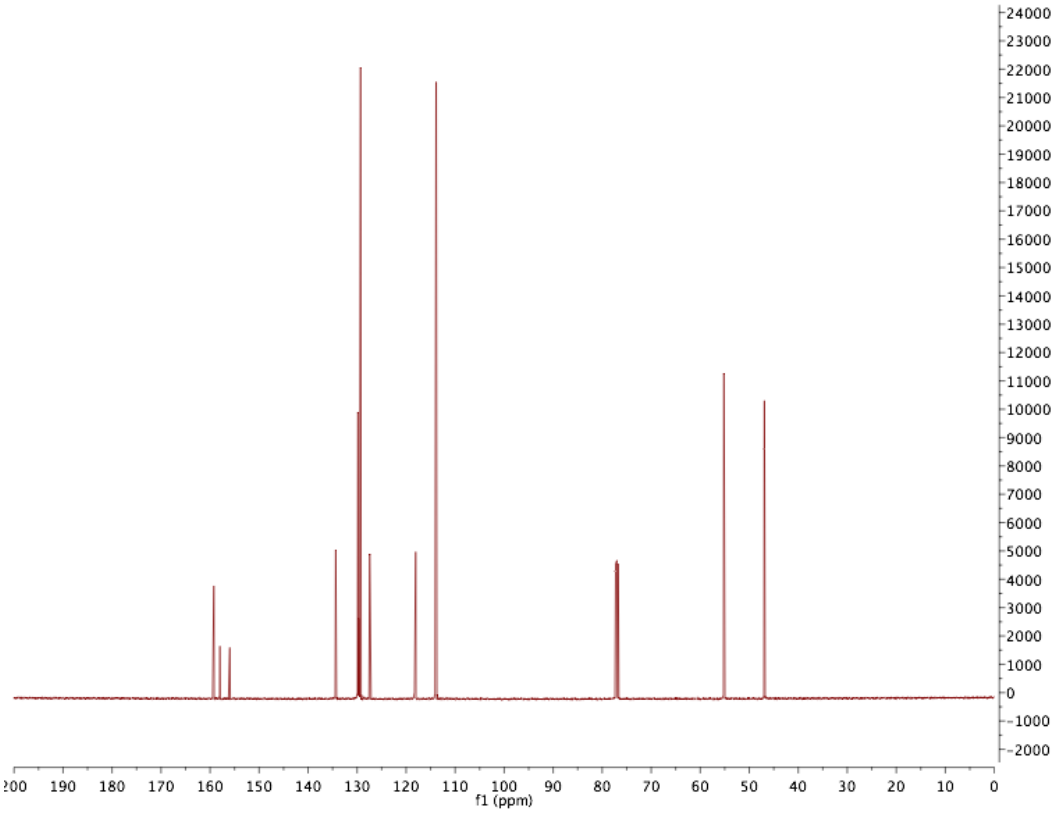
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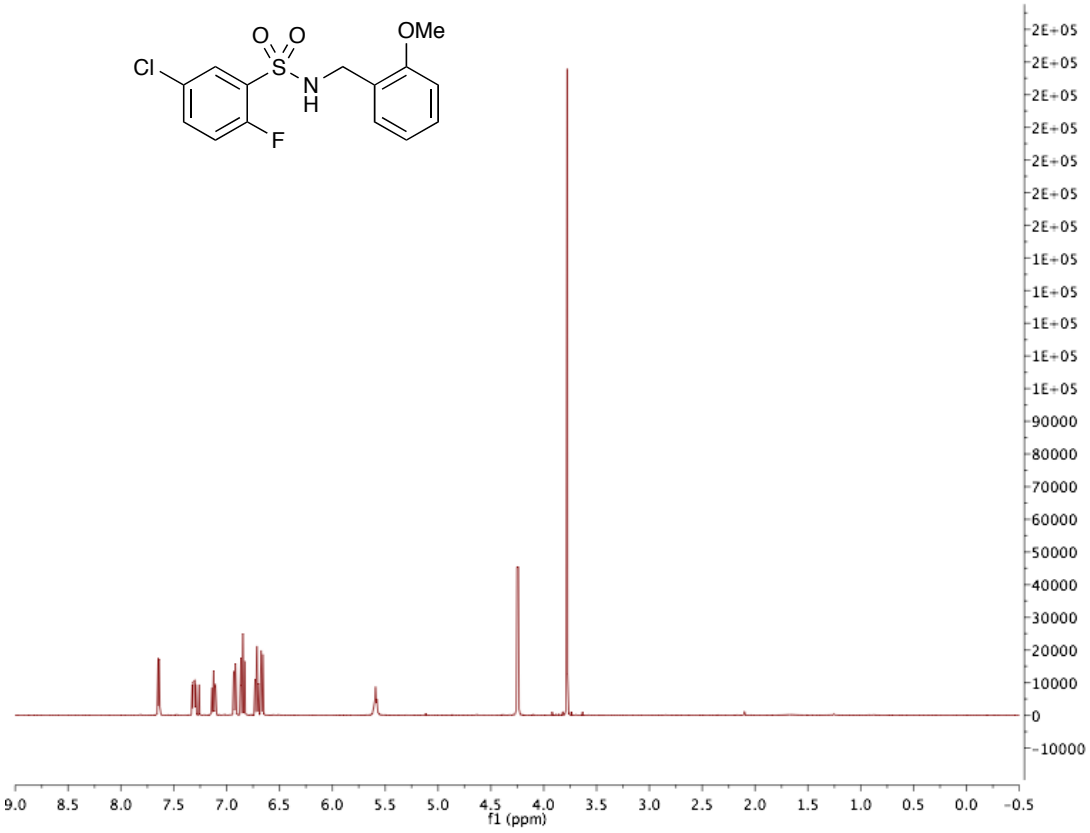
f1 (ppm)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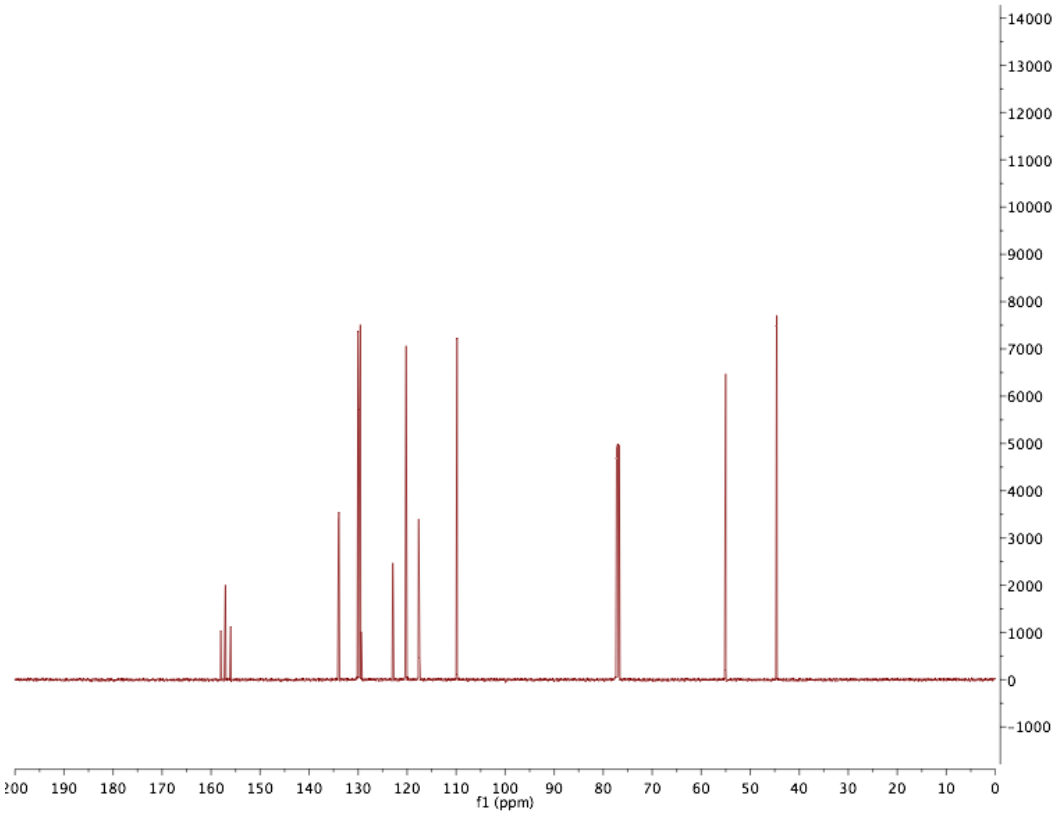
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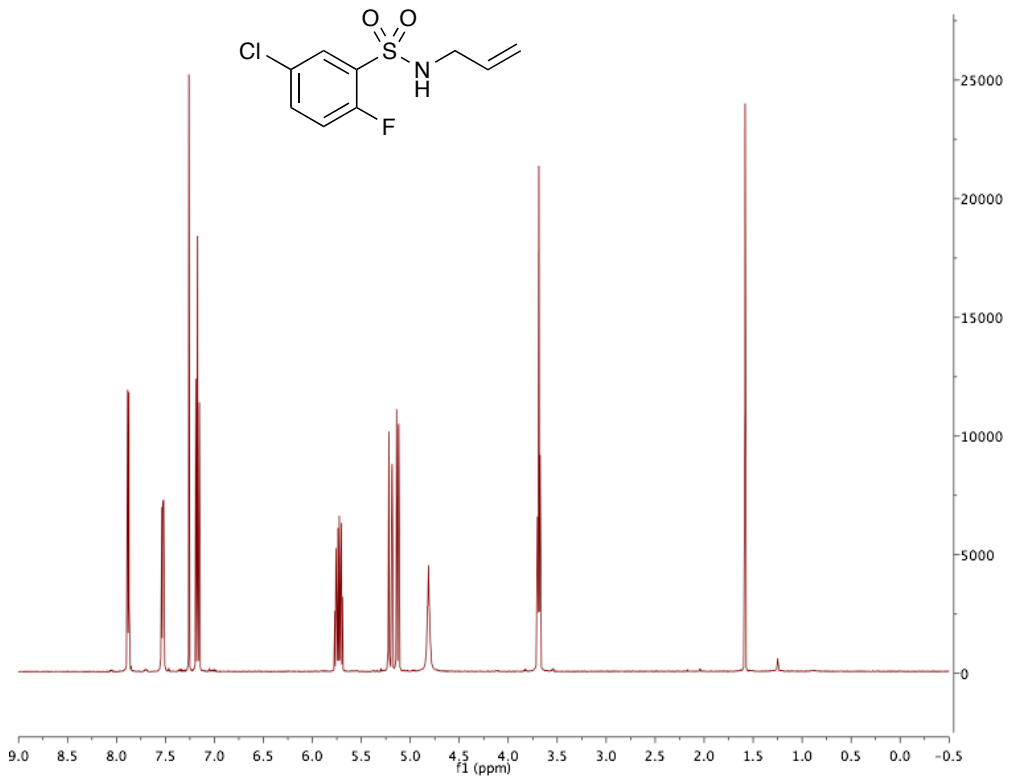
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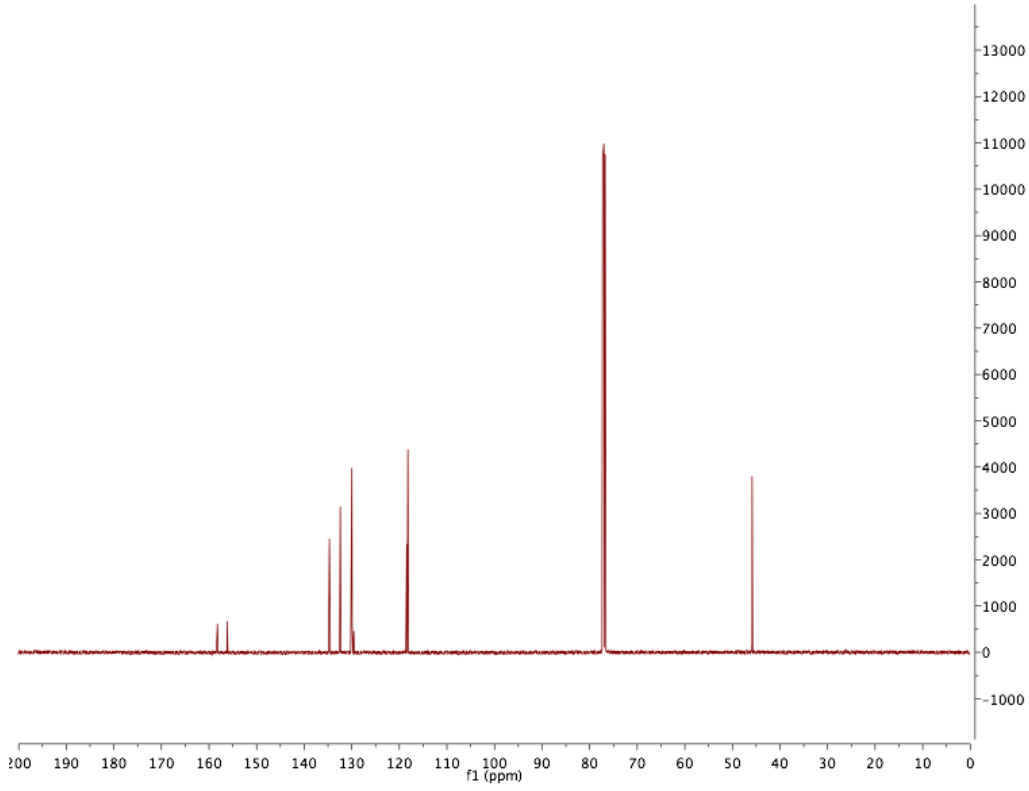
f1 (ppm)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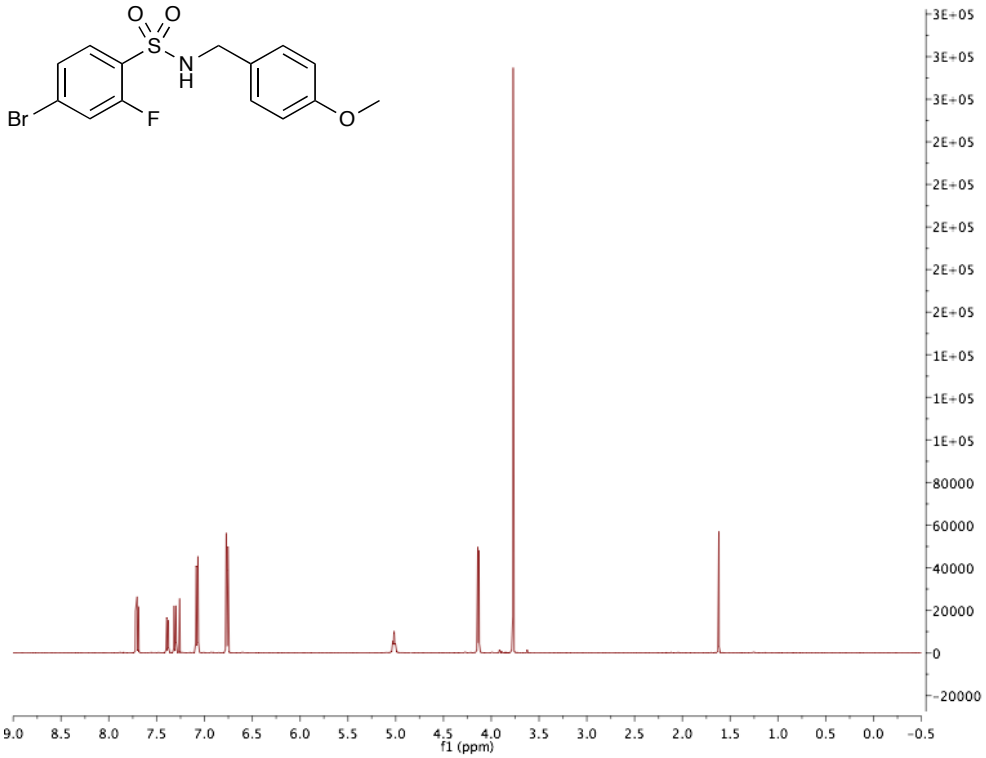
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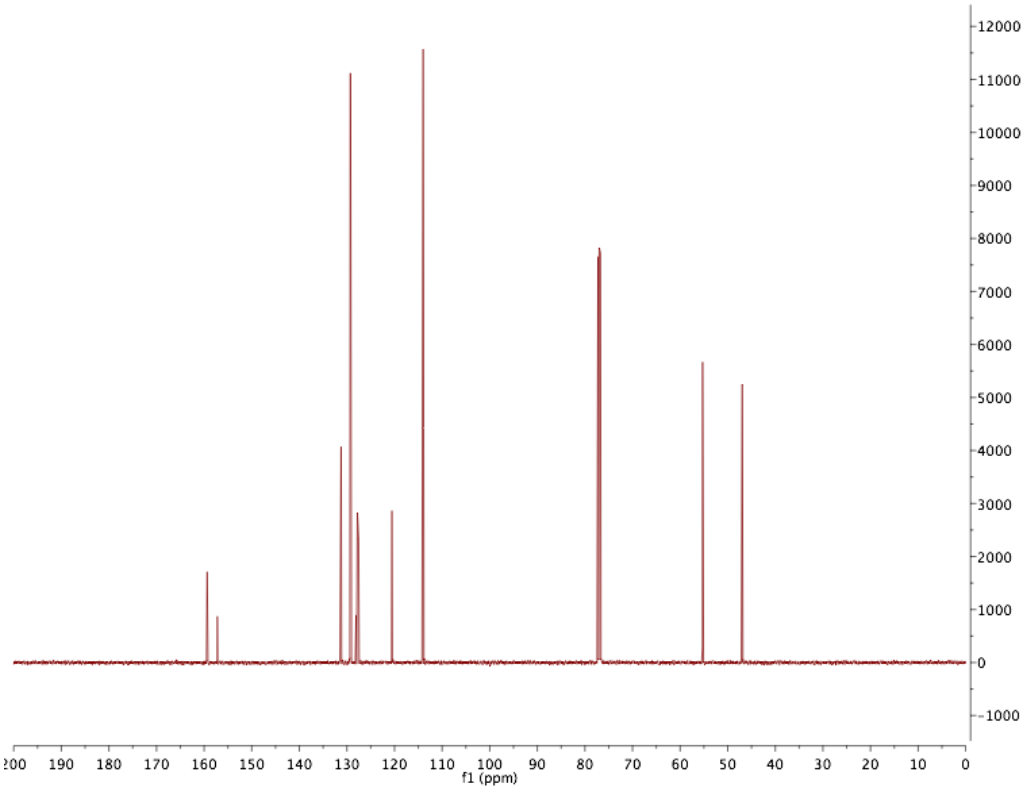
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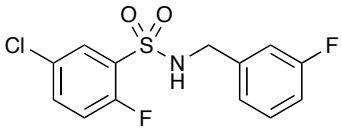
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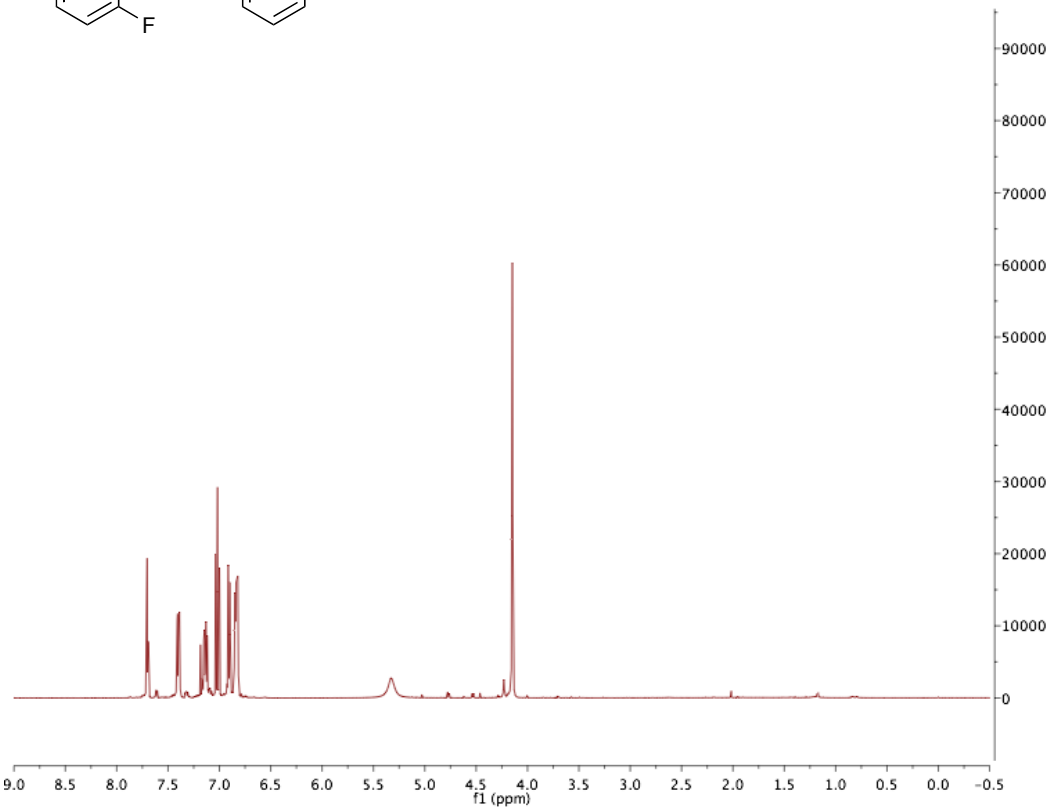
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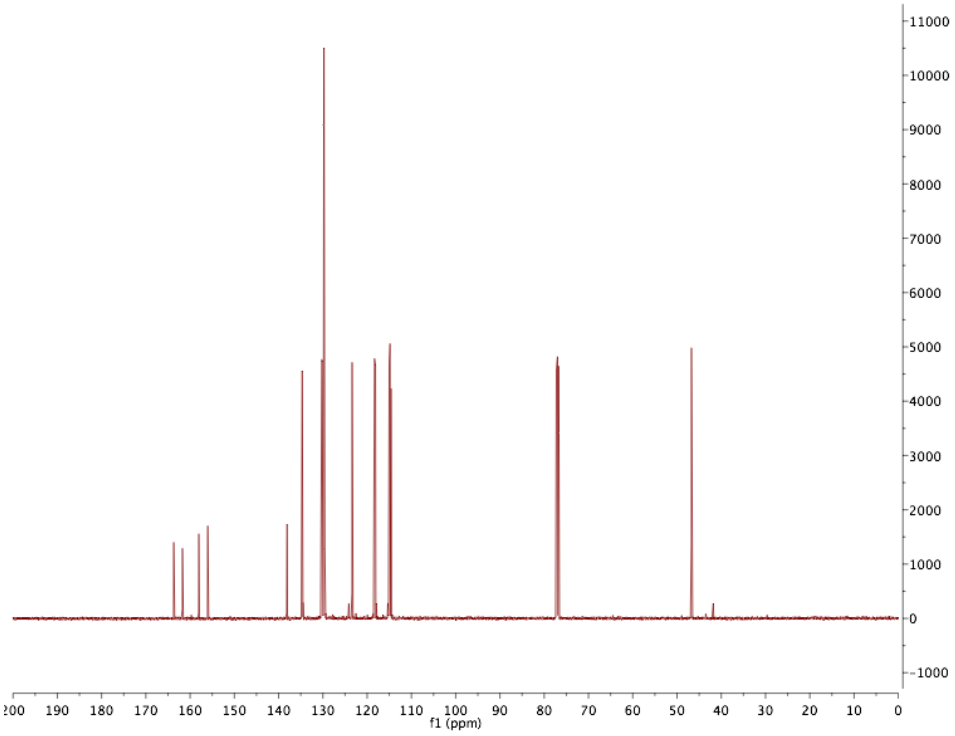
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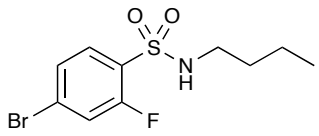
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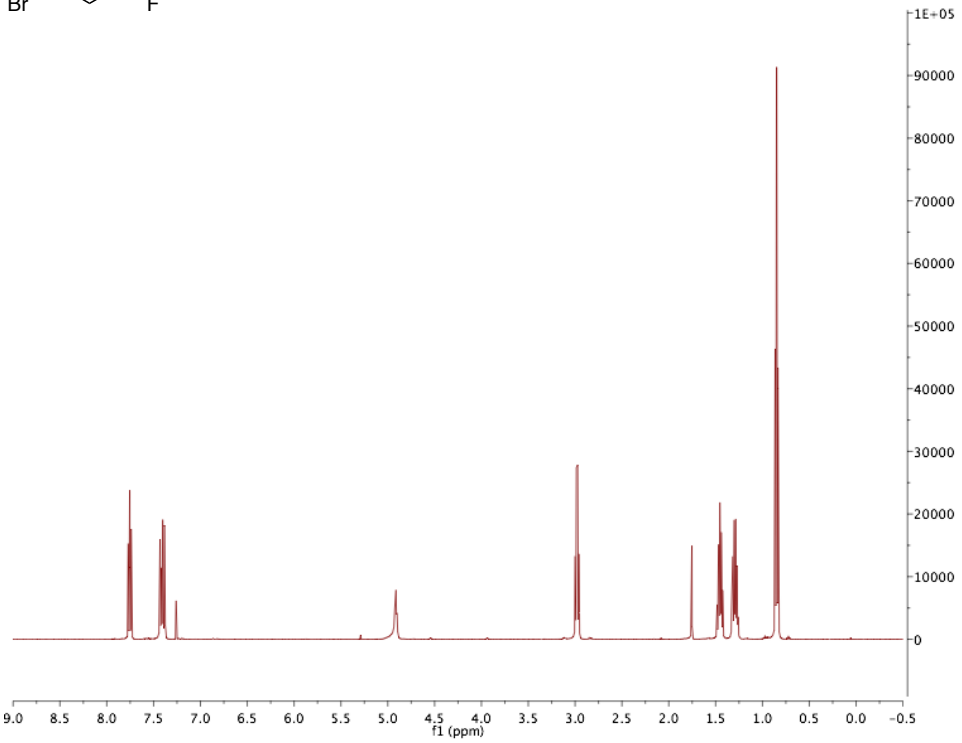
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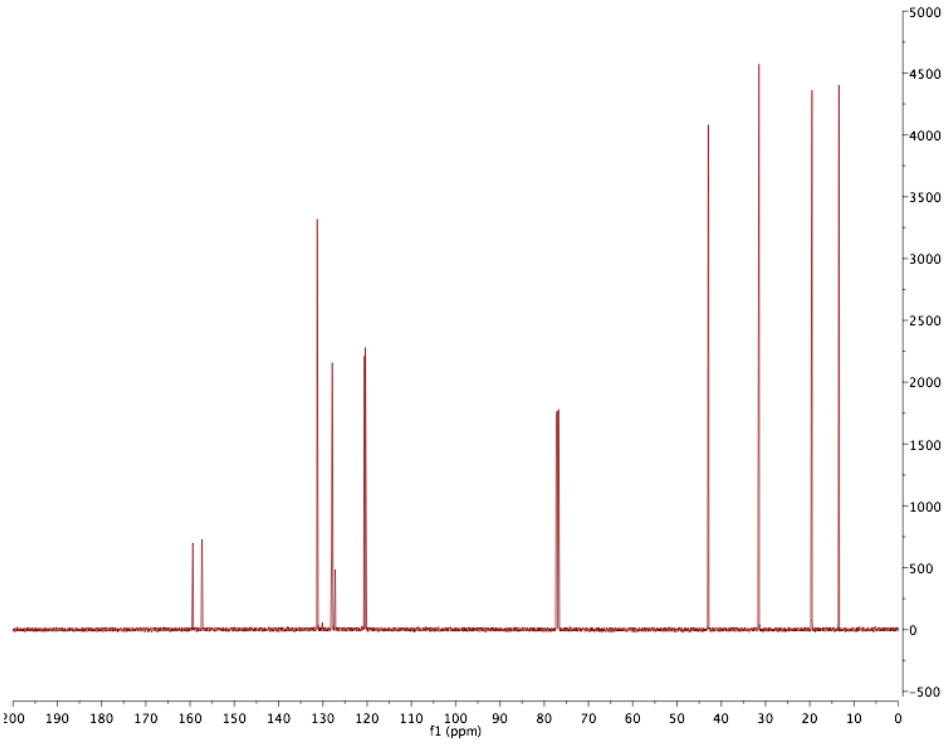
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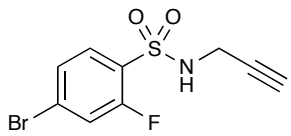
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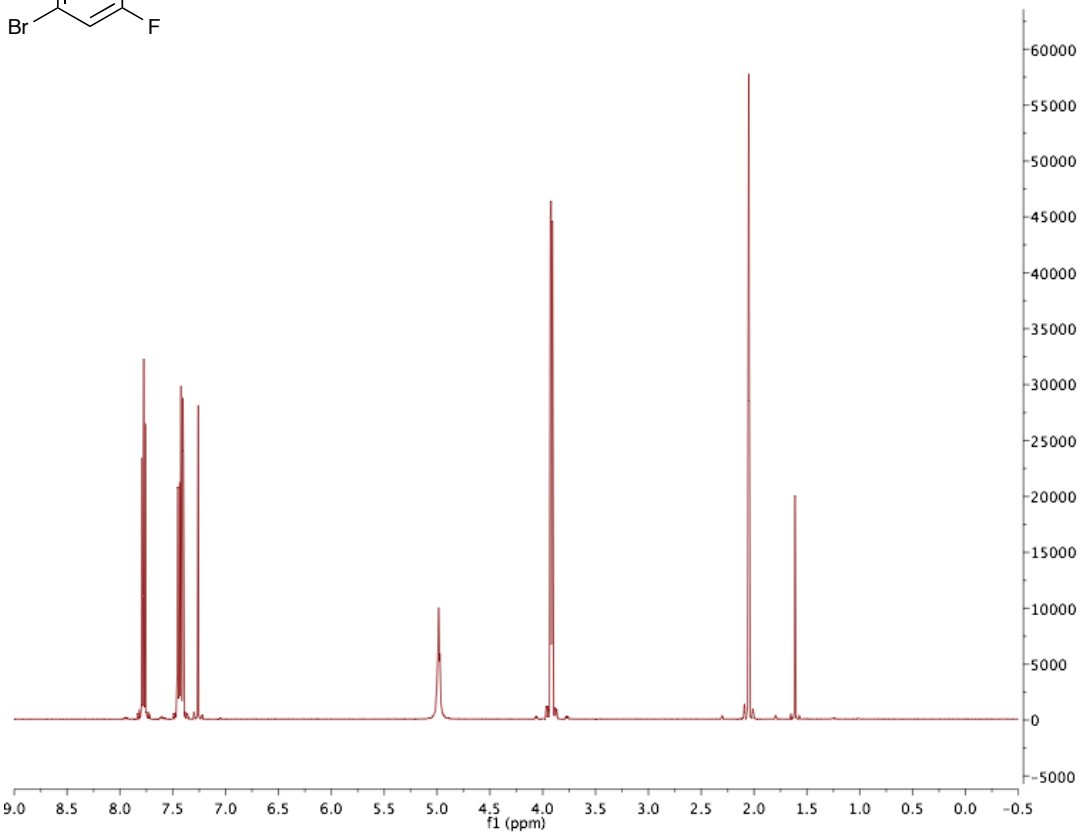
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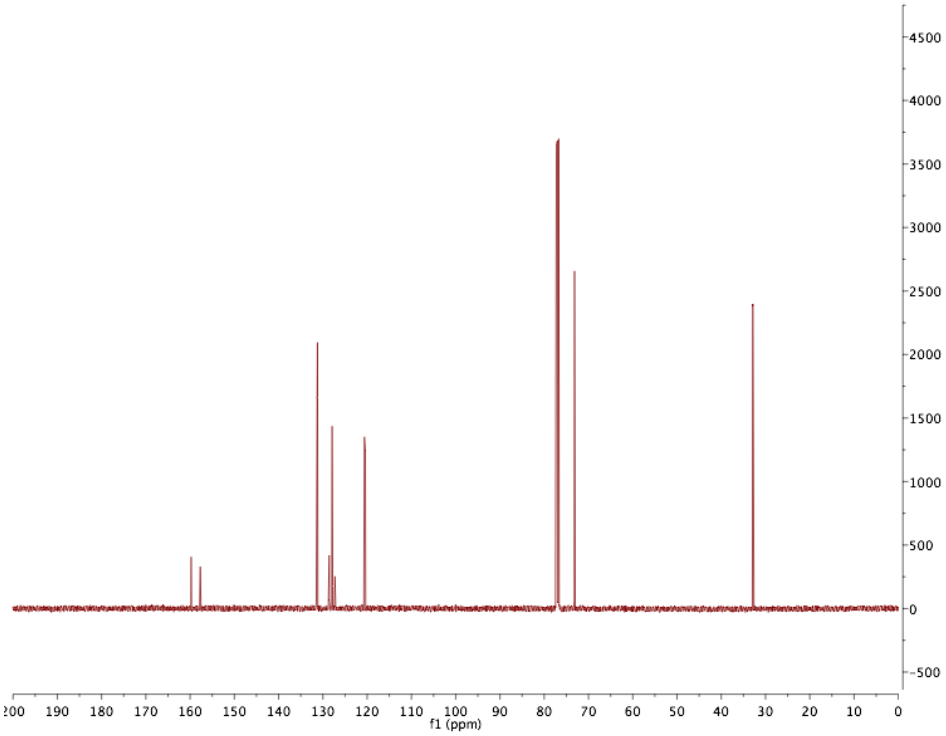
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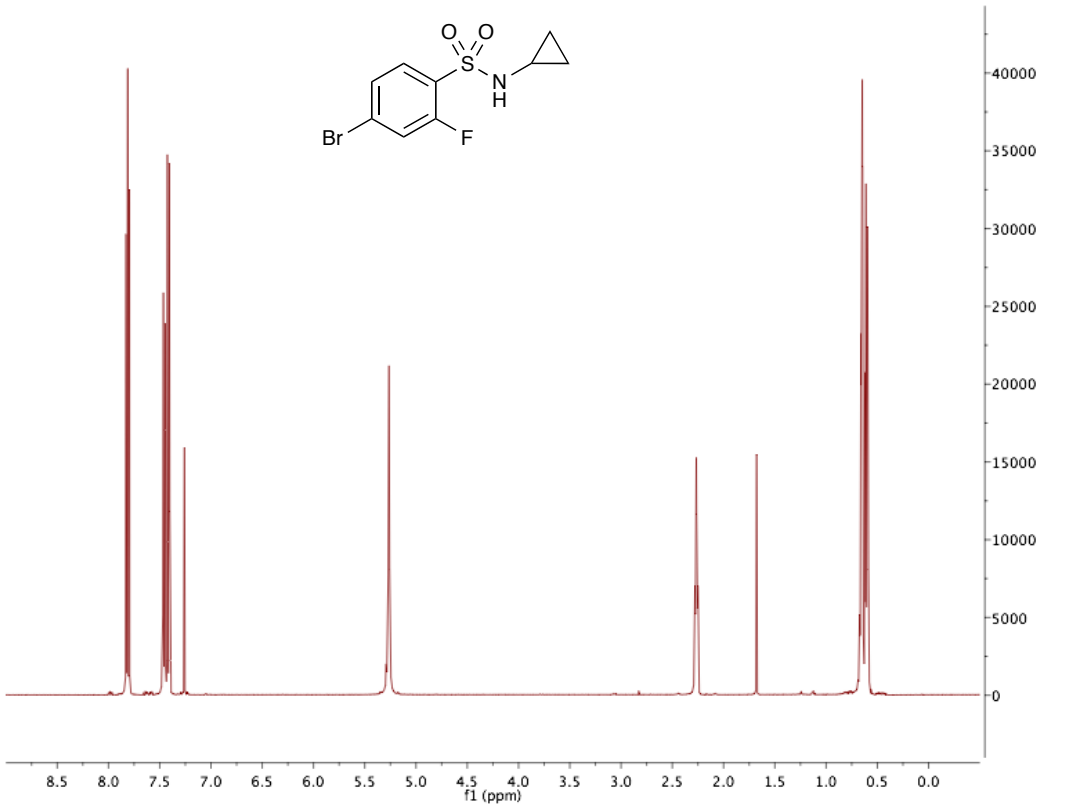
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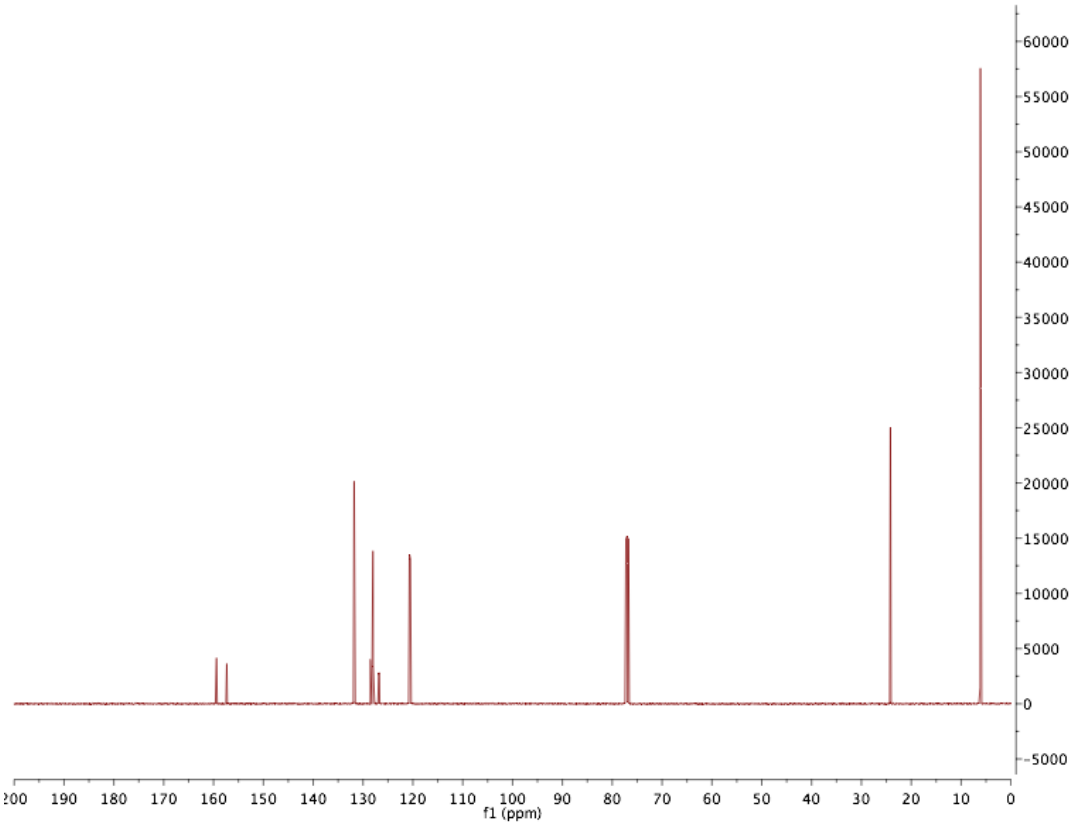
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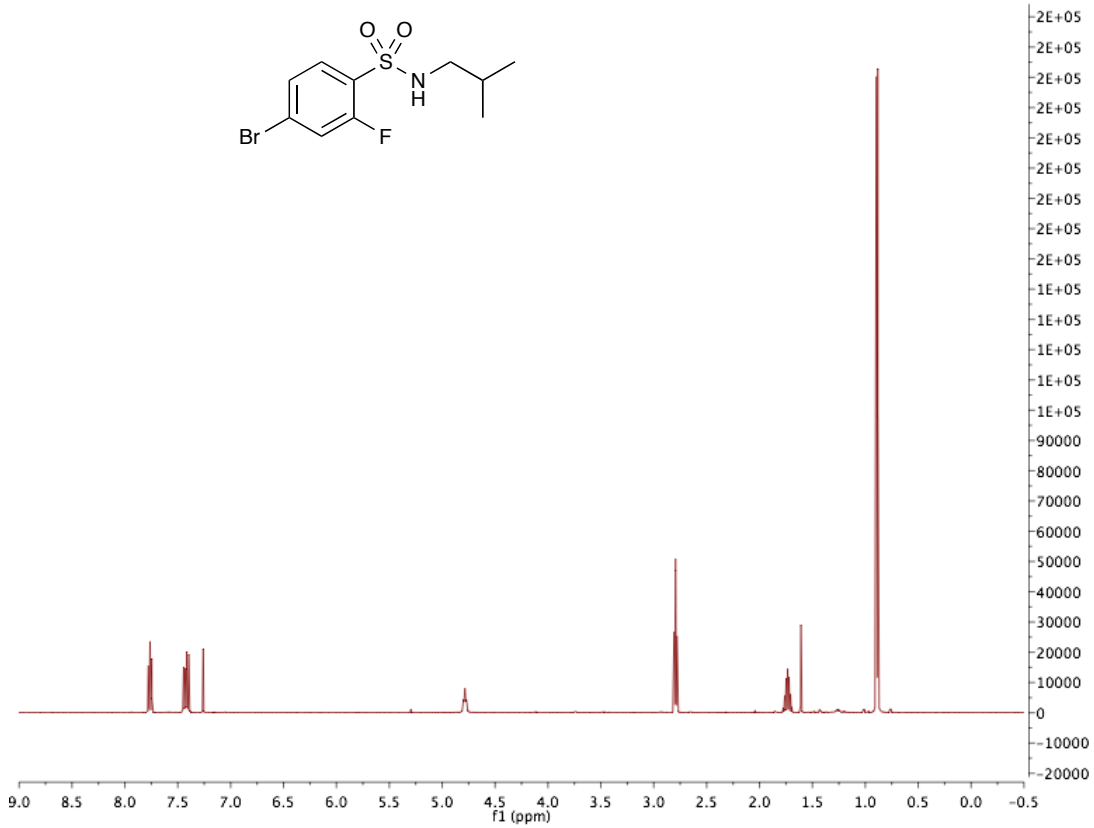
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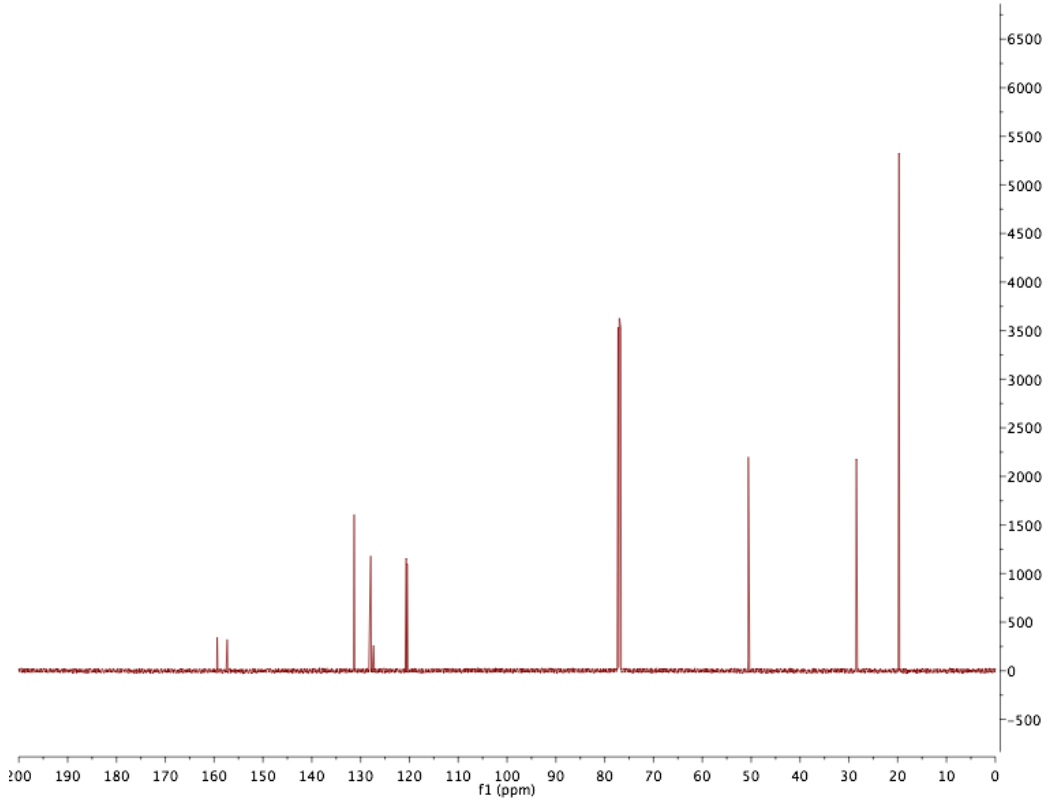
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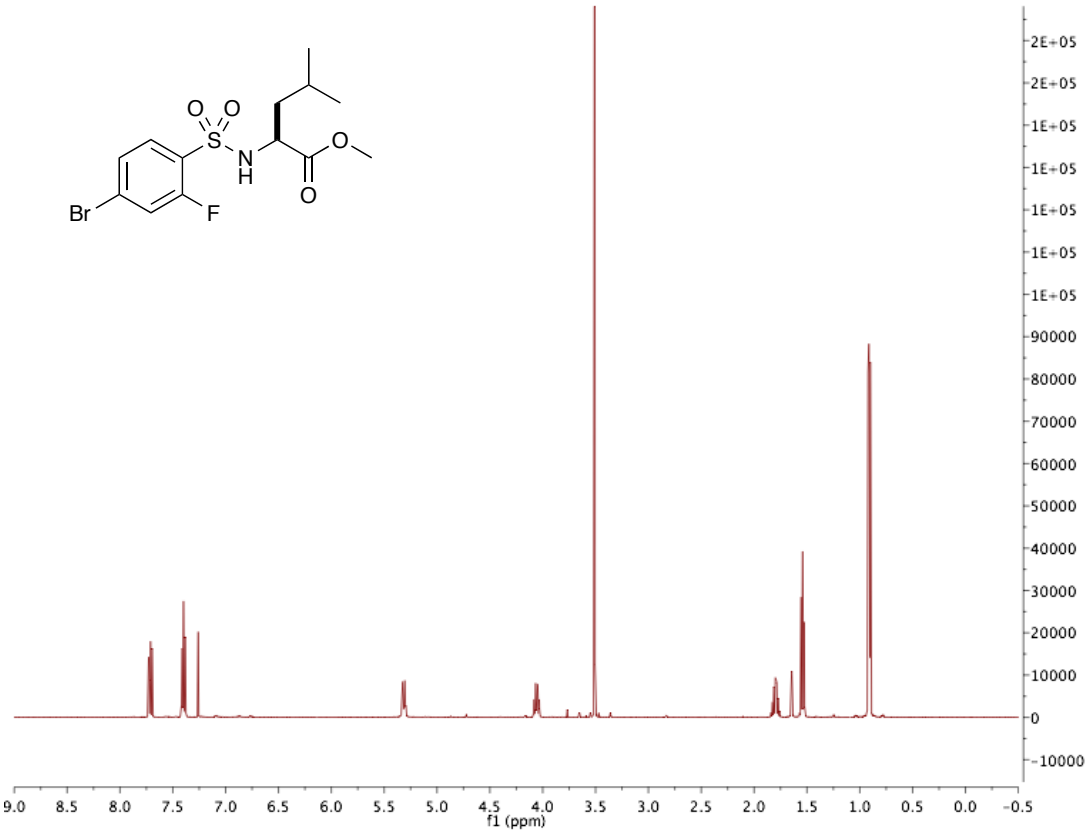
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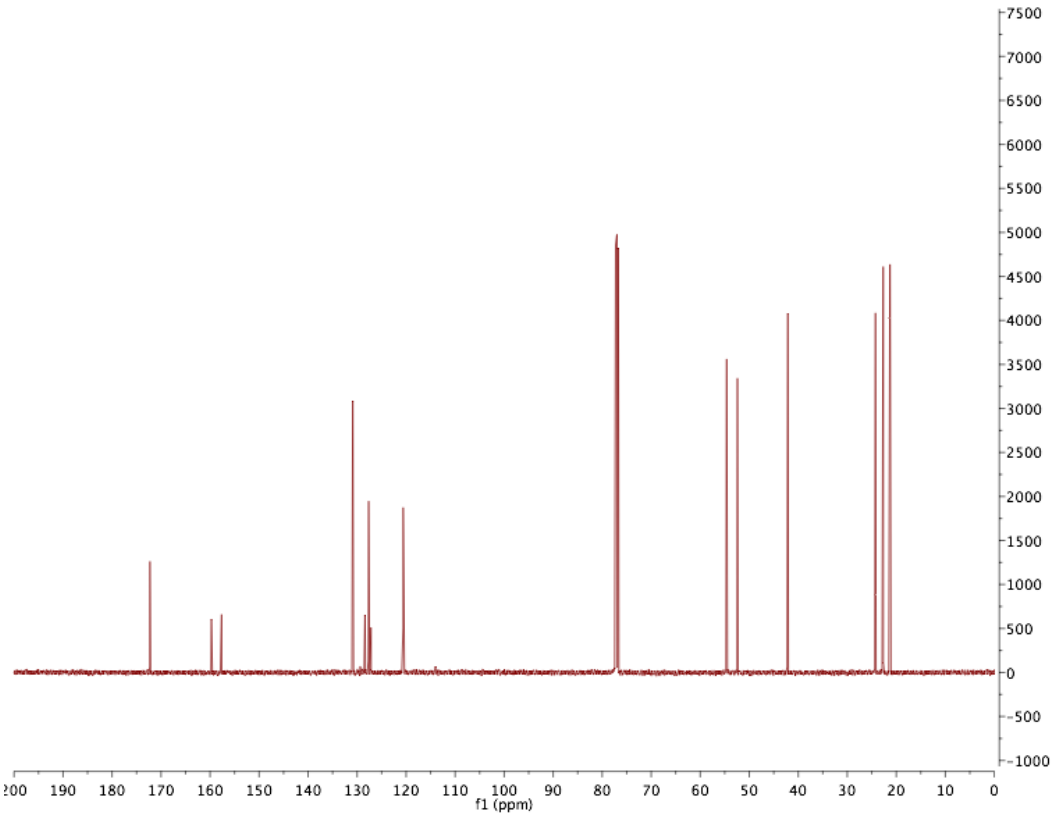
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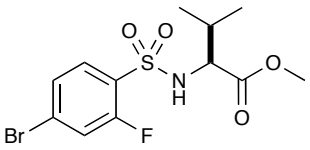
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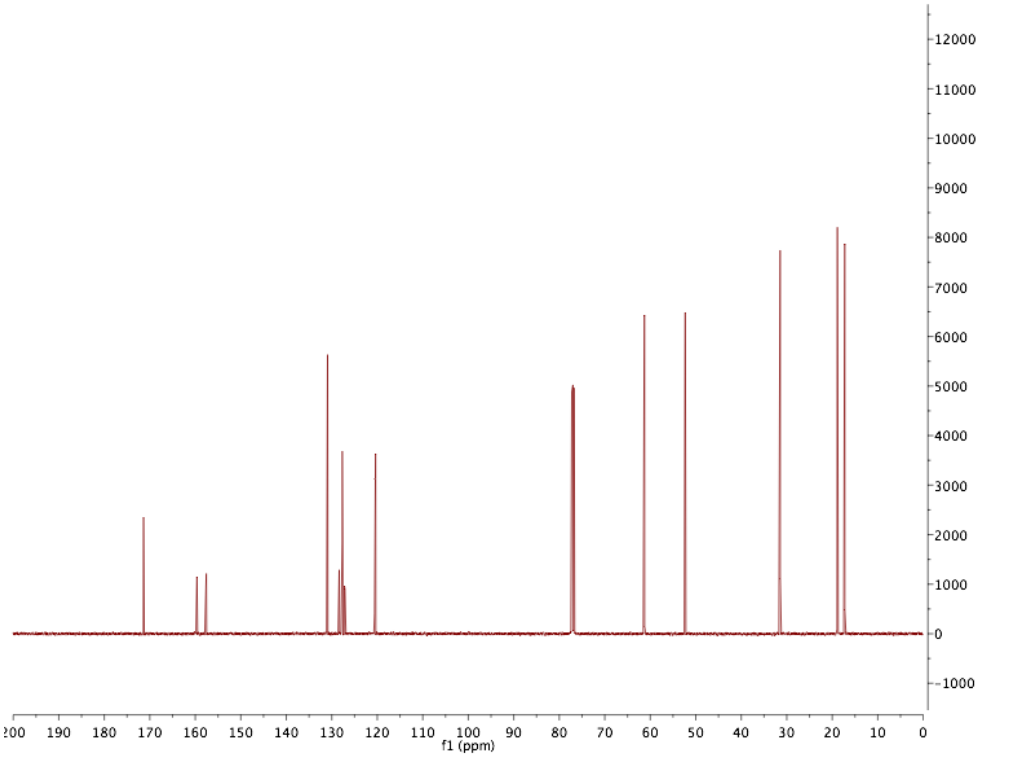
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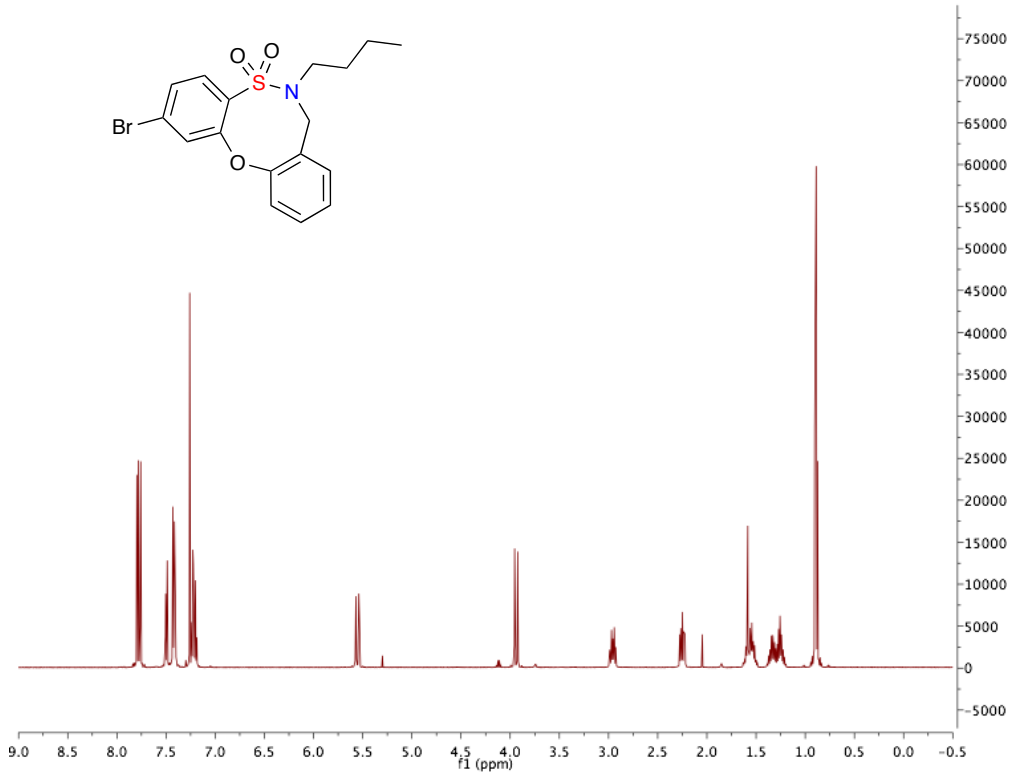
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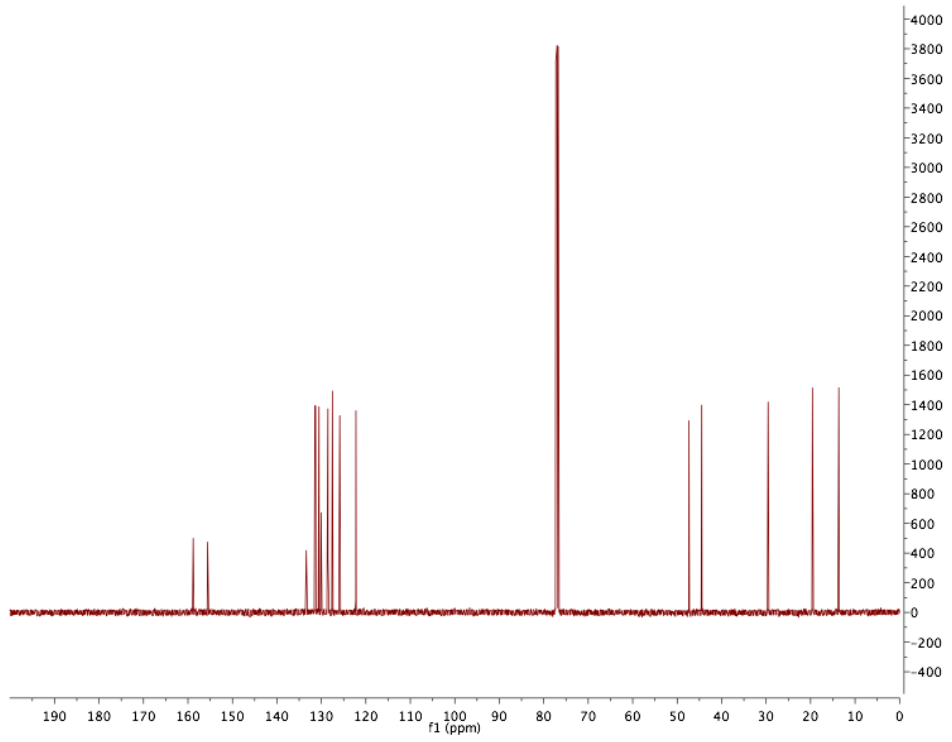
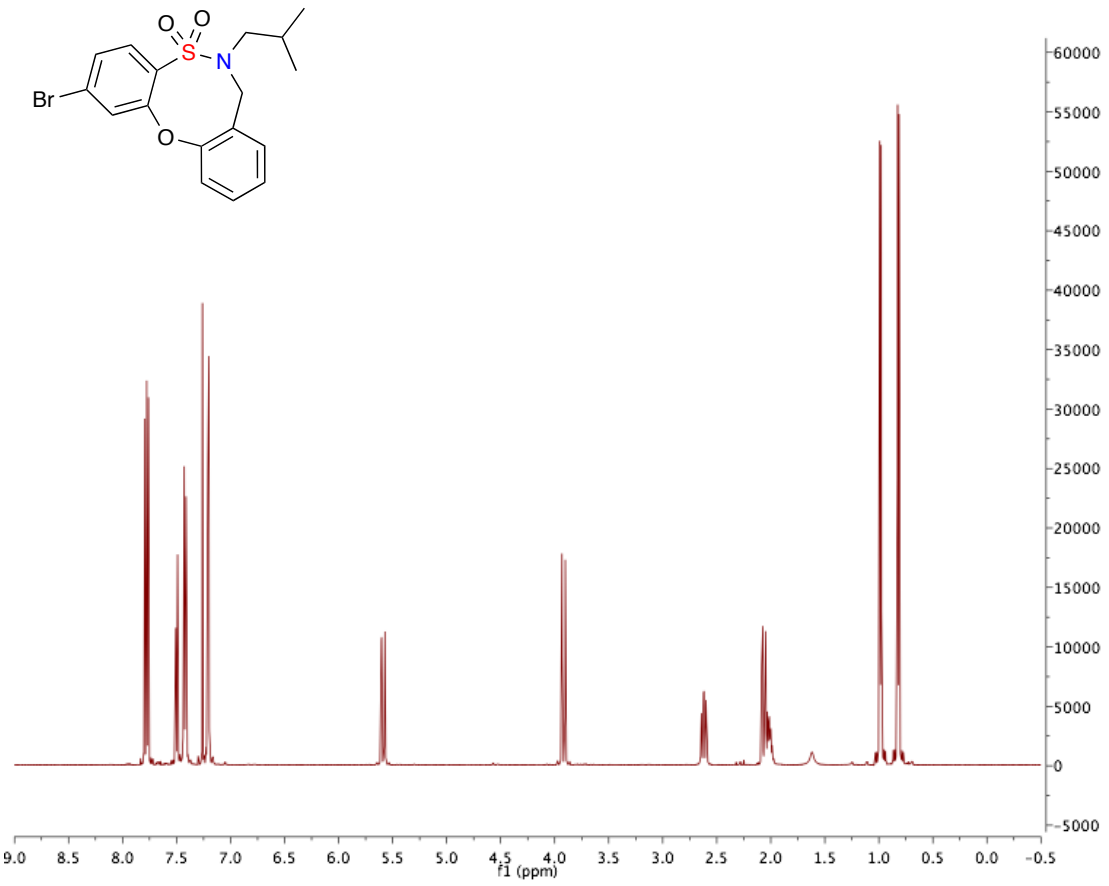
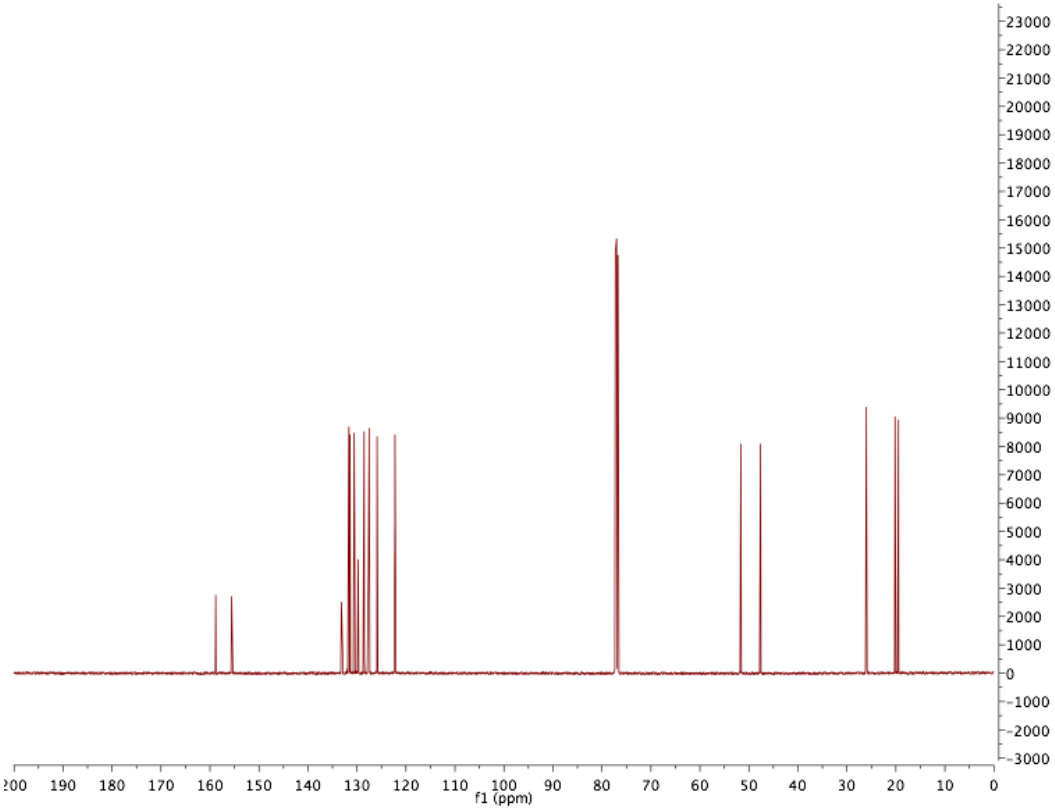
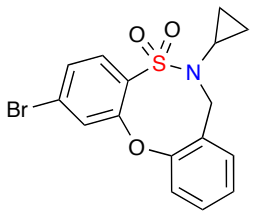
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)

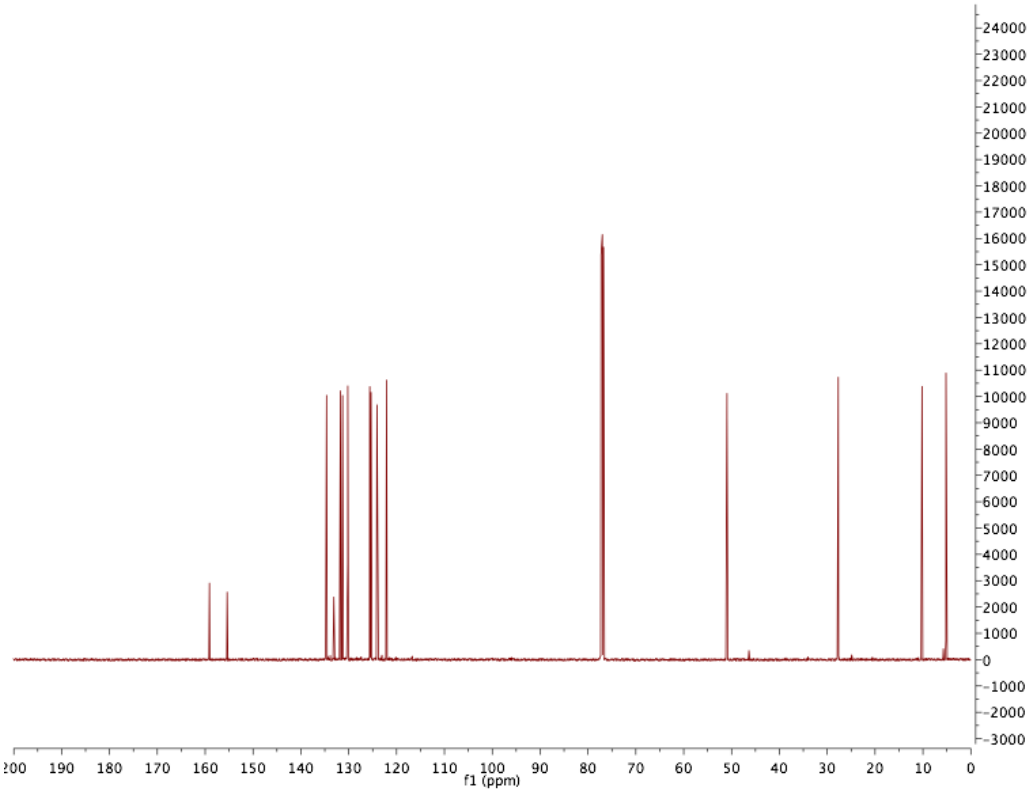

4000
3800
3600
3400
3200
3000
2800
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
-200
-400
190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

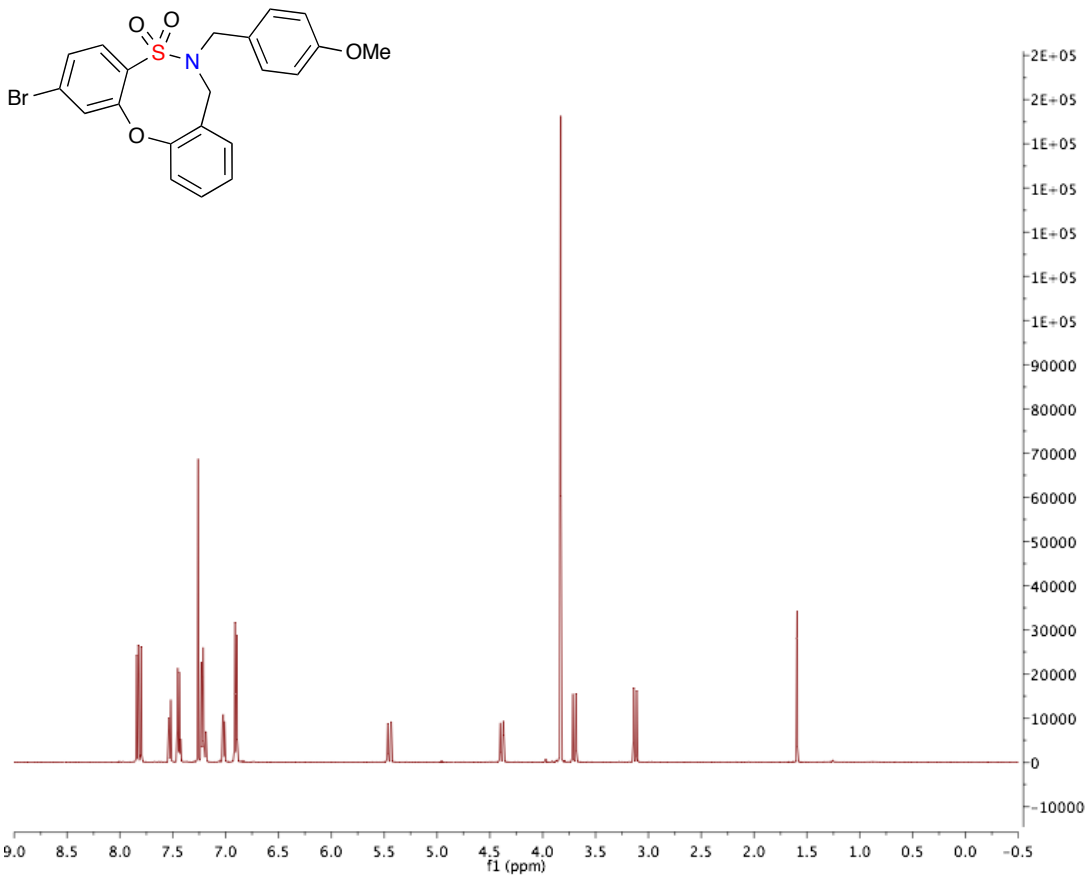

O
O
S
N
Br
O
60000
55000
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
-5000
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)

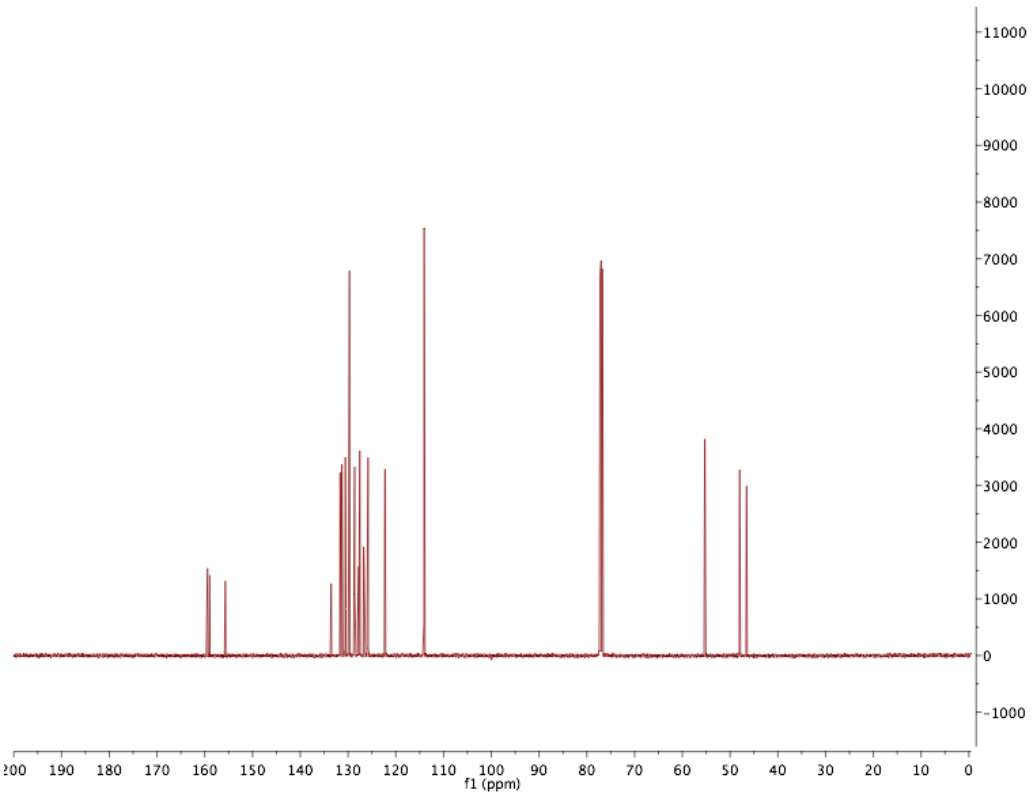

23000
22000
21000
20000
19000
18000
17000
16000
15000
14000
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
-1000
-2000
-3000
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

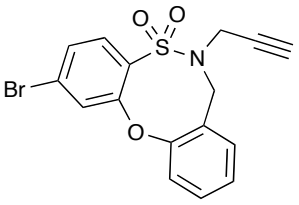

O
O
S
N
Br
O

50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)

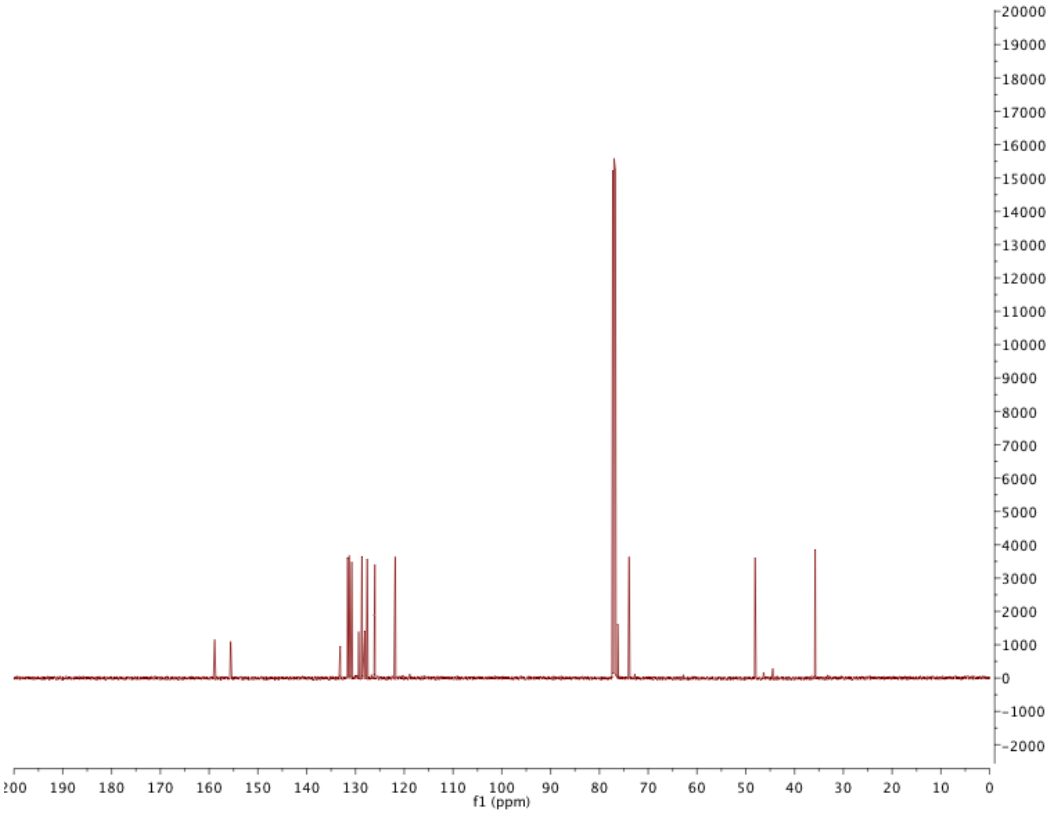

24000
23000
22000
21000
20000
19000
18000
17000
16000
15000
14000
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
-1000
-2000
-3000
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

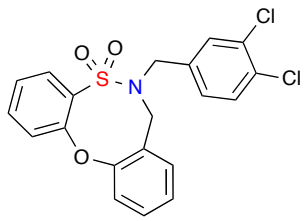

O
O
S
N
OMe
Br
O
2E+05
2E+05
1E+05
1E+05
1E+05
1E+05
1E+05
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
-10000
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)


11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
-1000
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

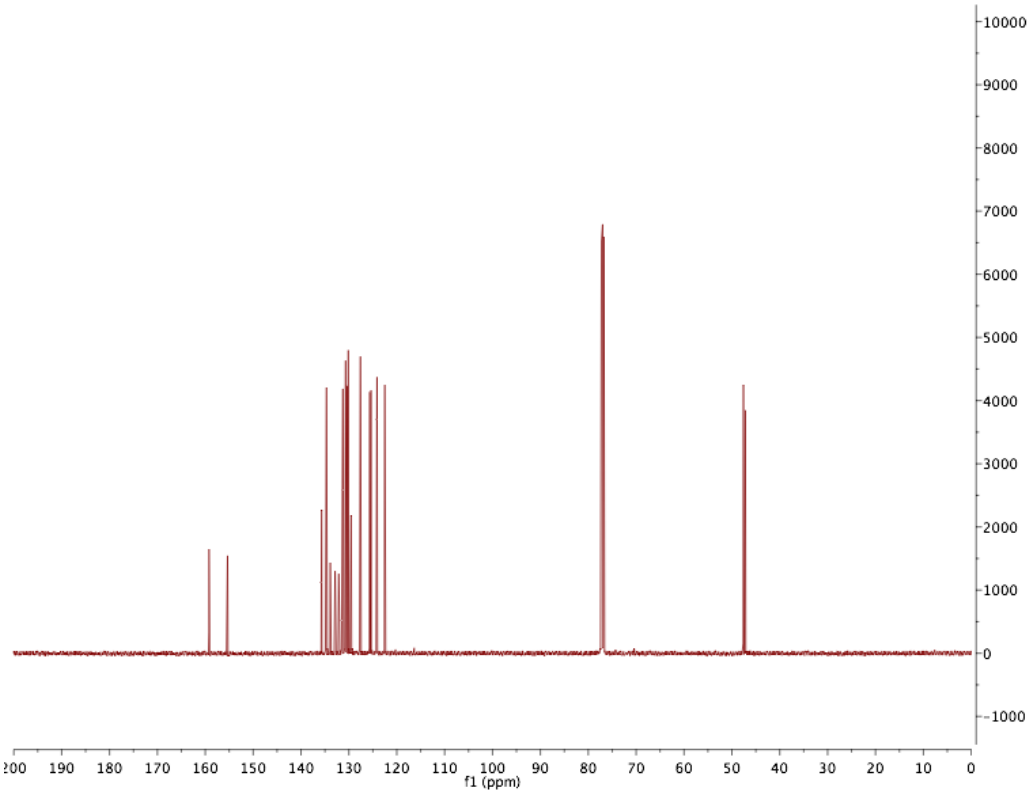

O
O
S
N
Br
O

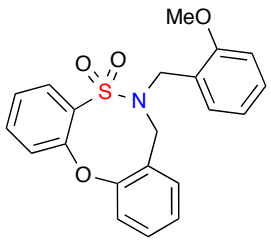
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)


20000
19000
18000
17000
16000
15000
14000
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
-1000
-2000
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

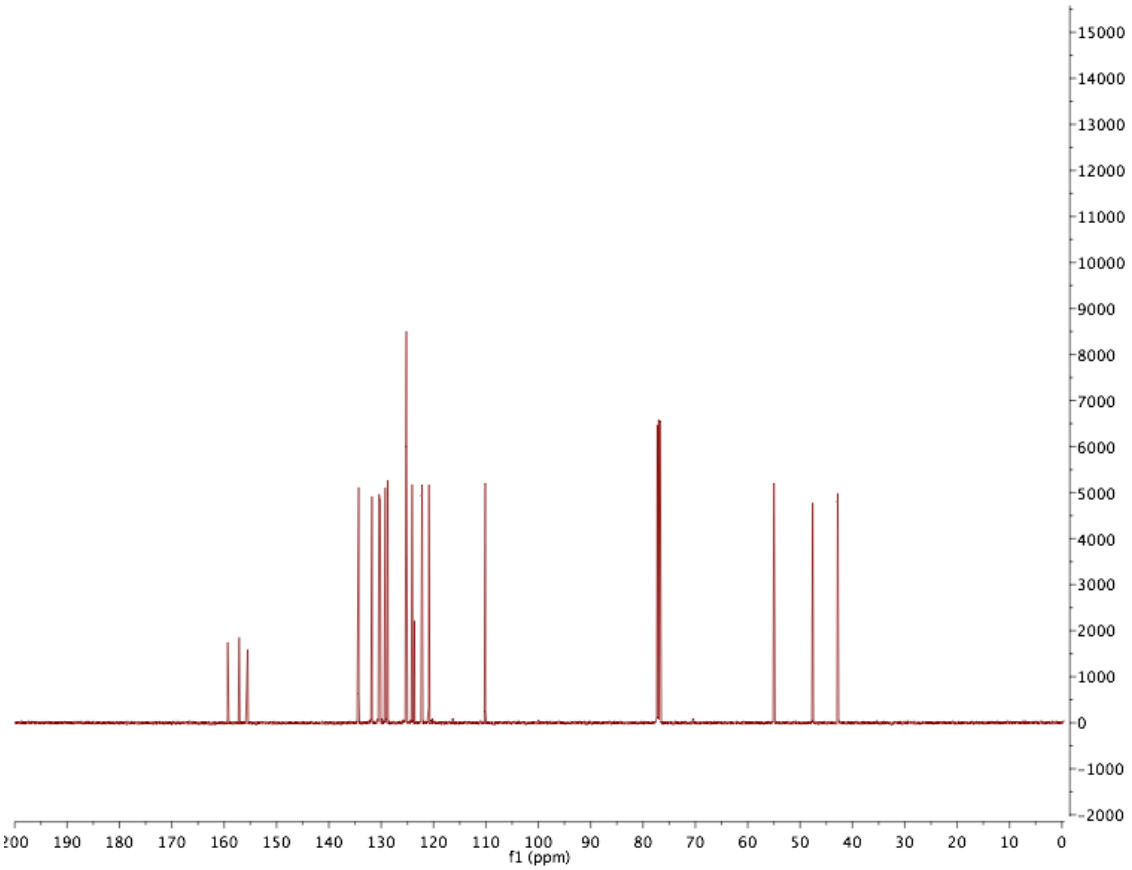

Cl
Cl
O
O
S
N
O

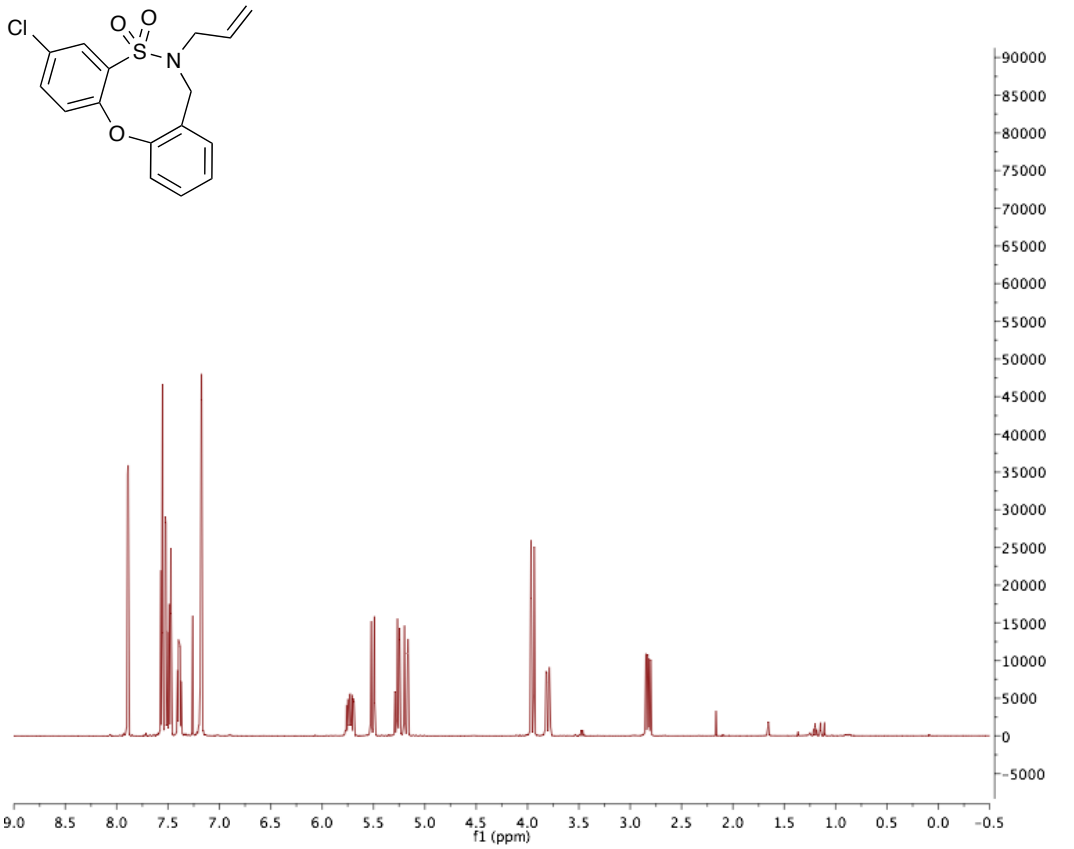
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)

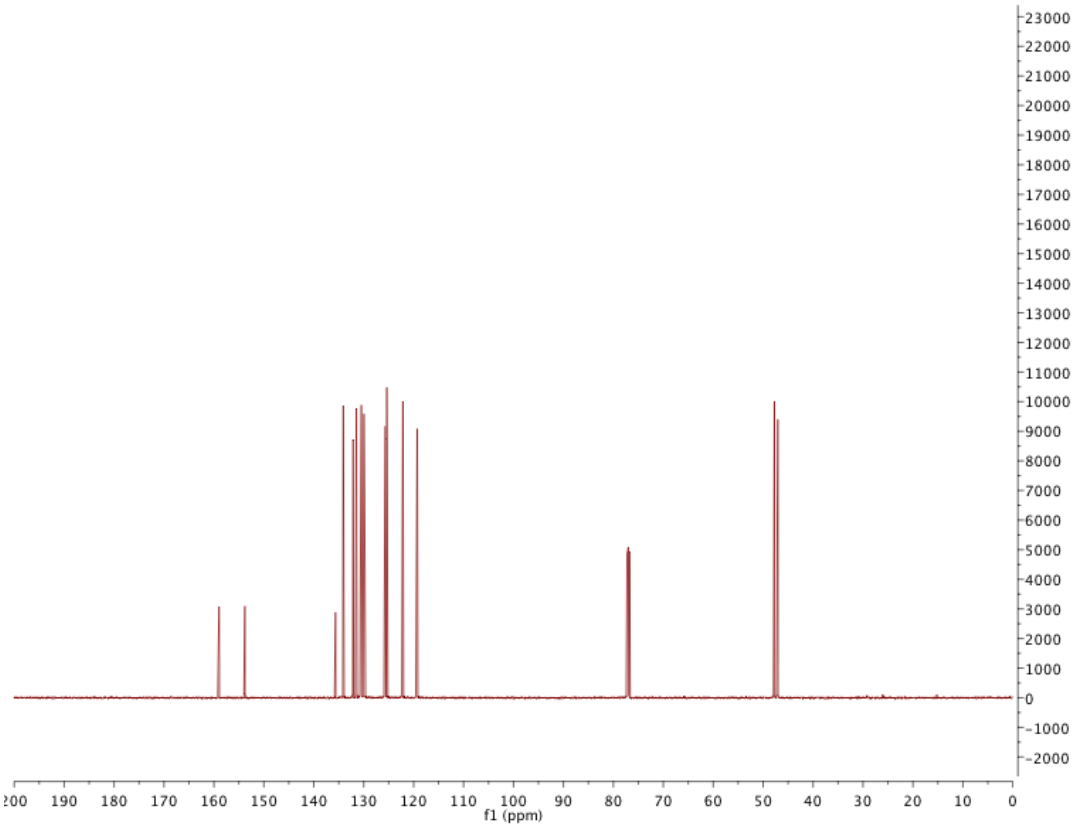

10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
-1000
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

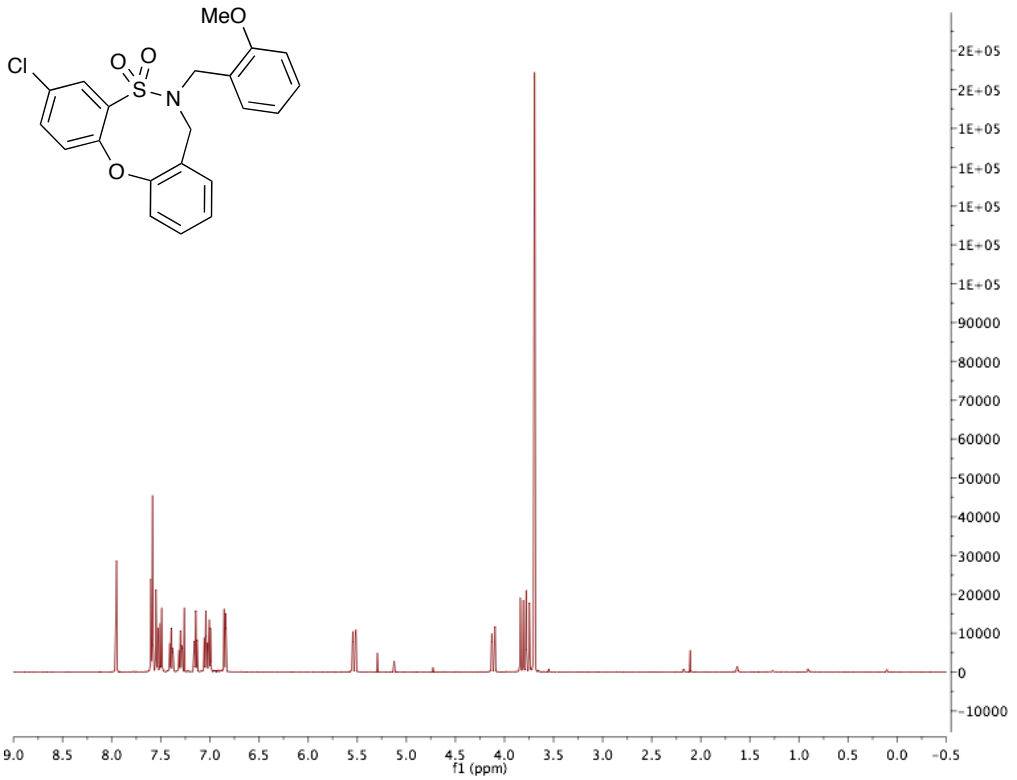

MeO
O
O
S
N
O

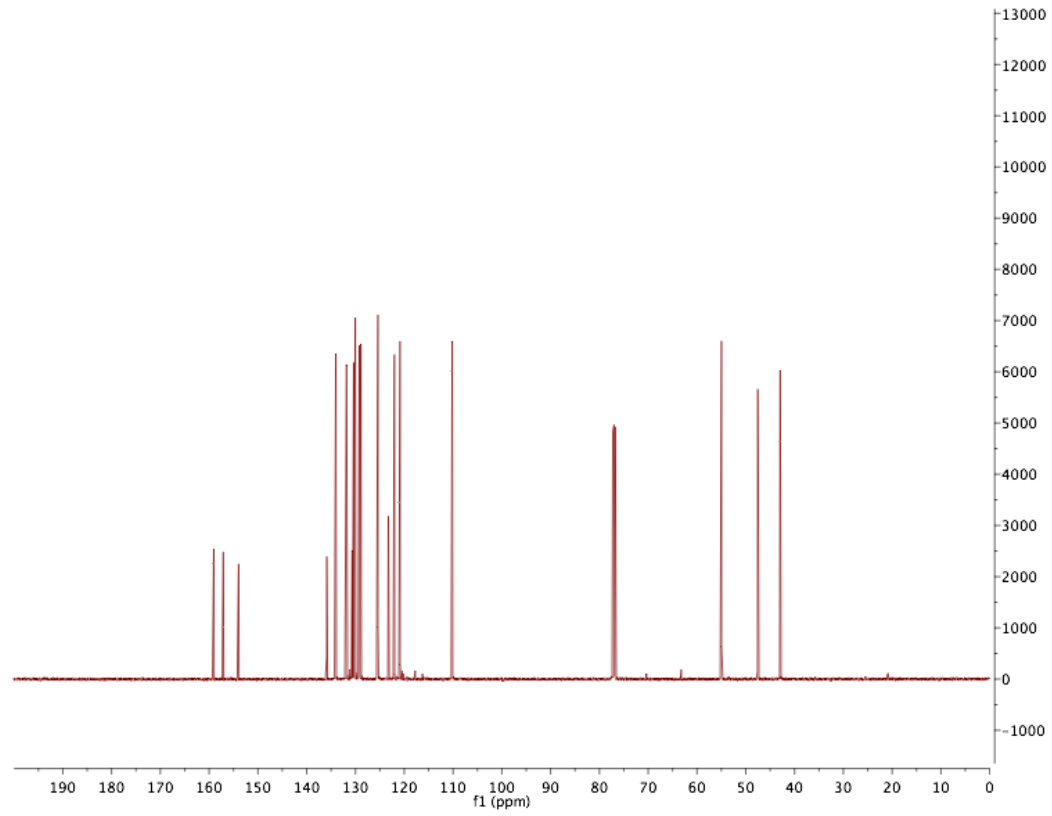
1E+05
1E+05
1E+05
1E+05
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
-10000
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)

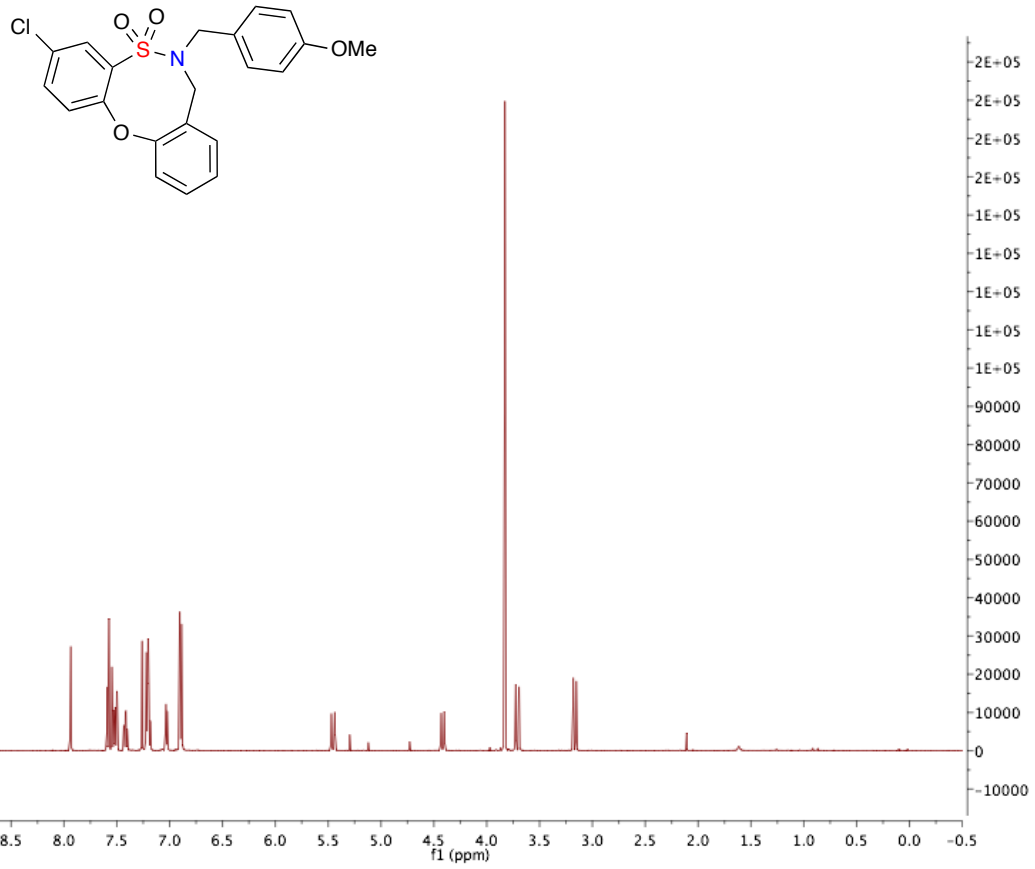

15000
14000
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
-1000
-2000
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

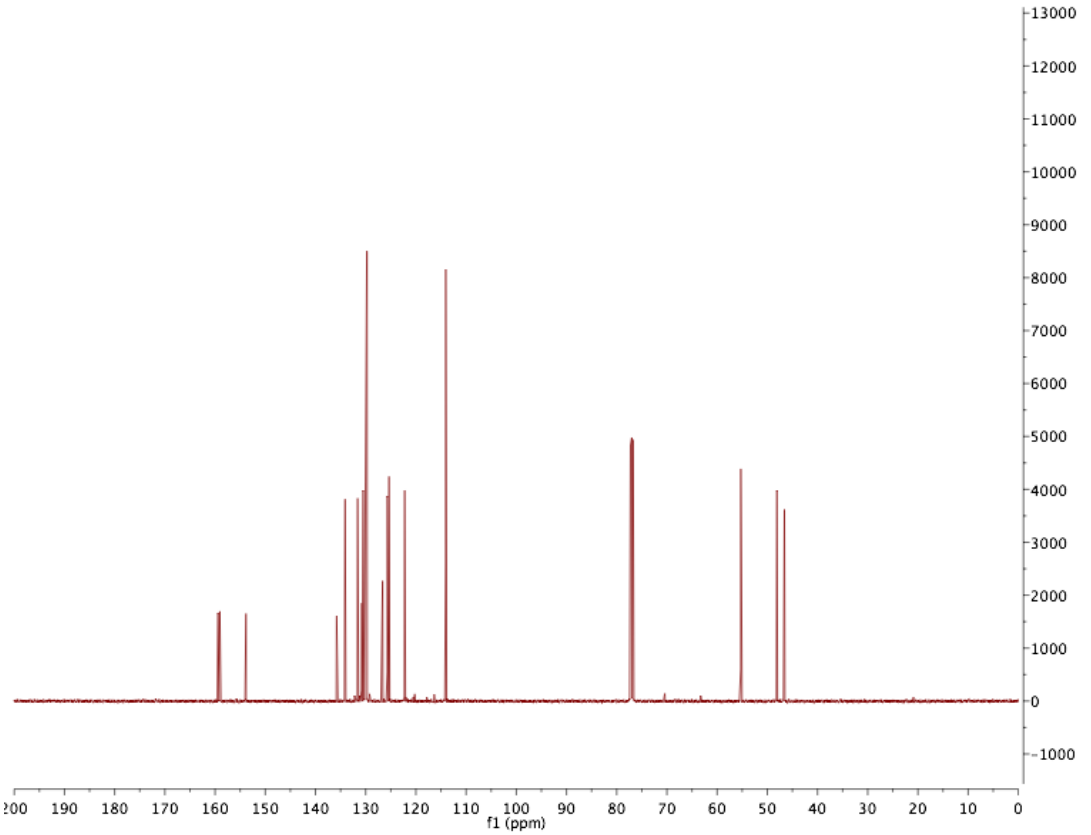

Cl
O
O
S
N
O
f1 (ppm)

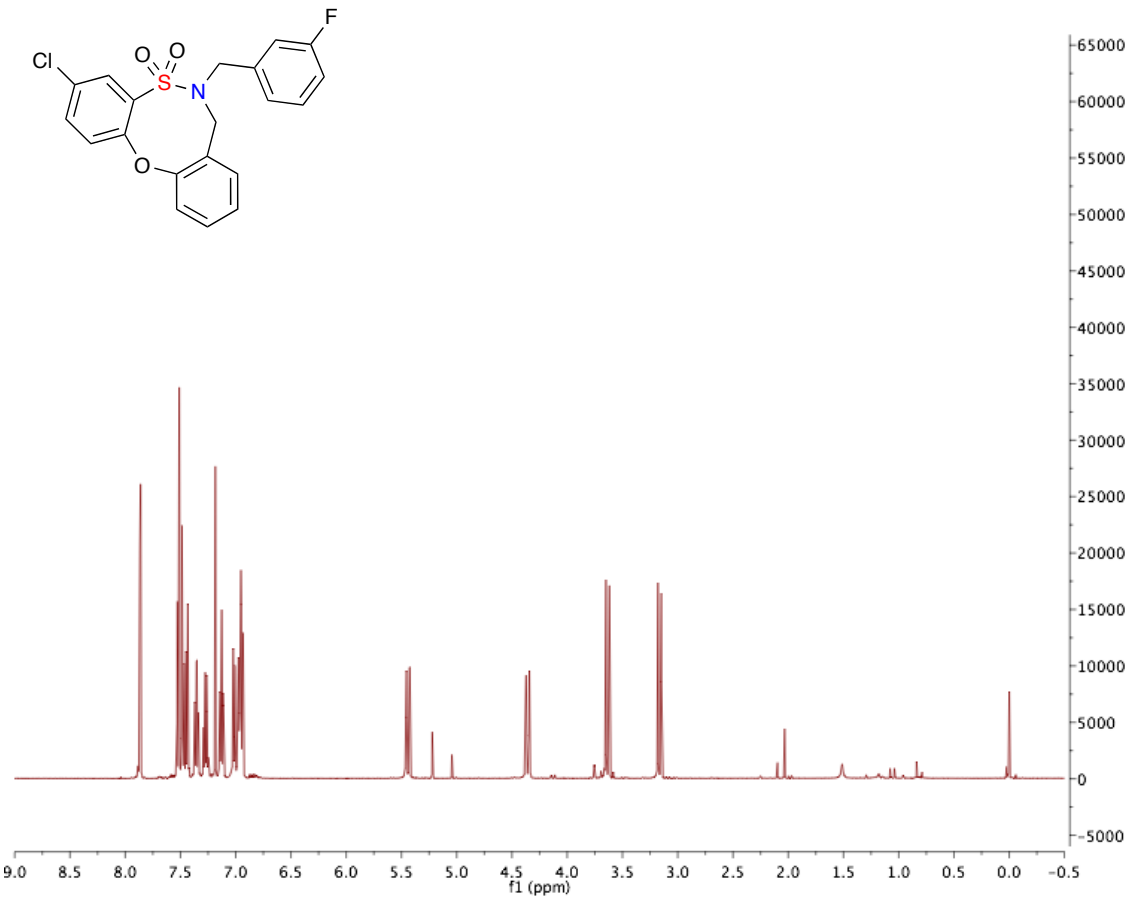

f1 (ppm)

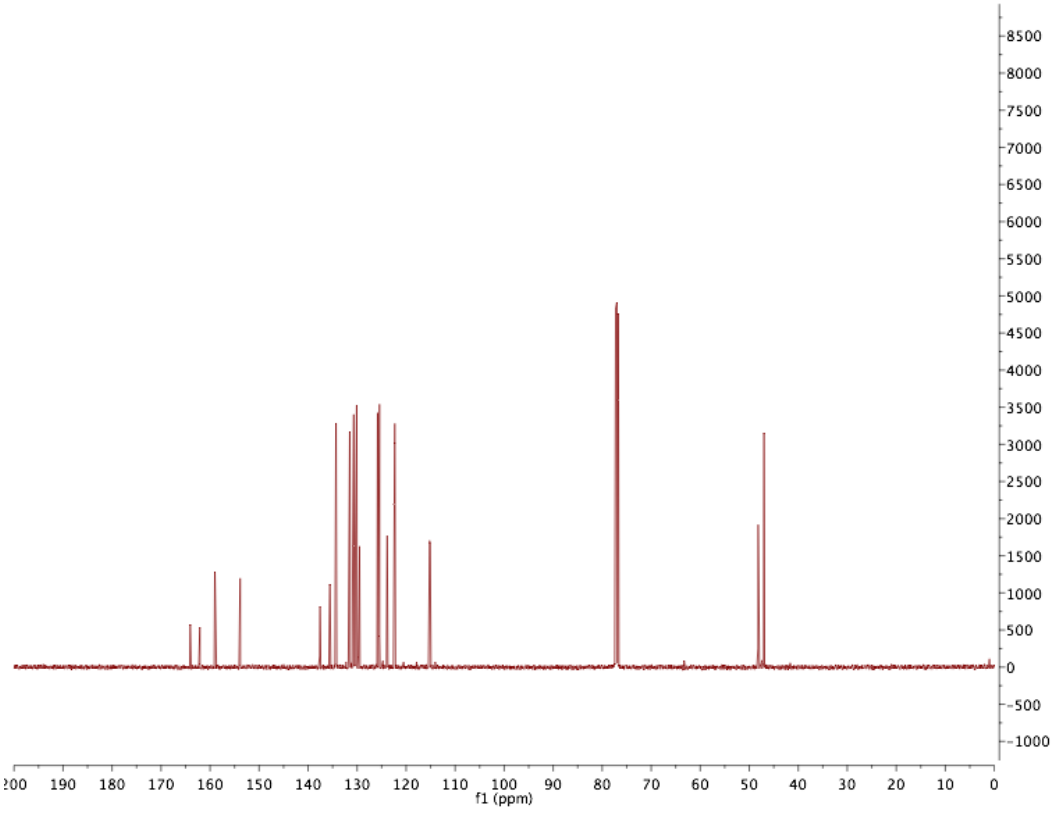

MeO
Cl
O
O
S
N
O
2E+05
2E+05
1E+05
1E+05
1E+05
1E+05
1E+05
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
-10000
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)

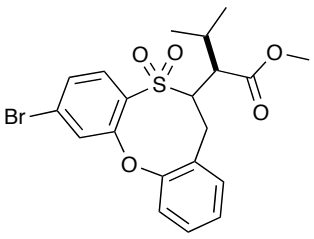

13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
-1000
190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


Cl
O
O
S
N
OMe
O
2E+05
2E+05
2E+05
2E+05
1E+05
1E+05
1E+05
1E+05
1E+05
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
-10000
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)

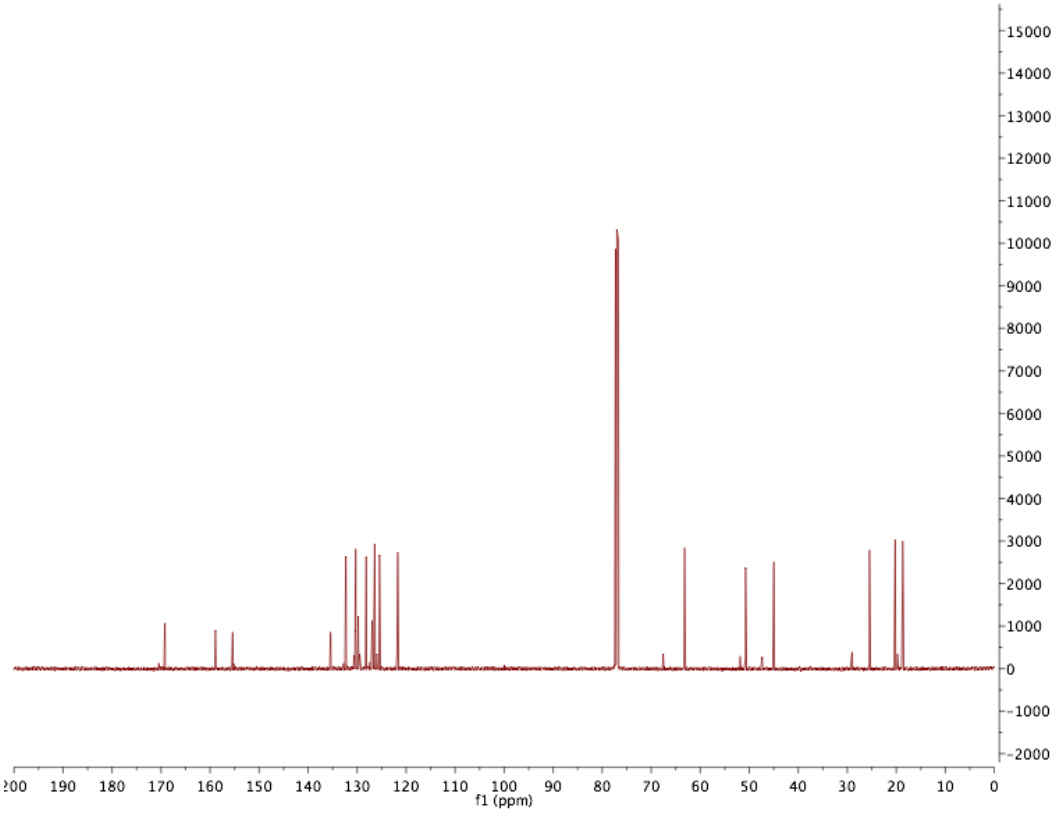

13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
-1000
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

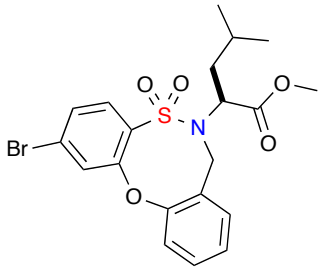

Cl
O
O
S
N
F
O
f1 (ppm)


f1 (ppm)

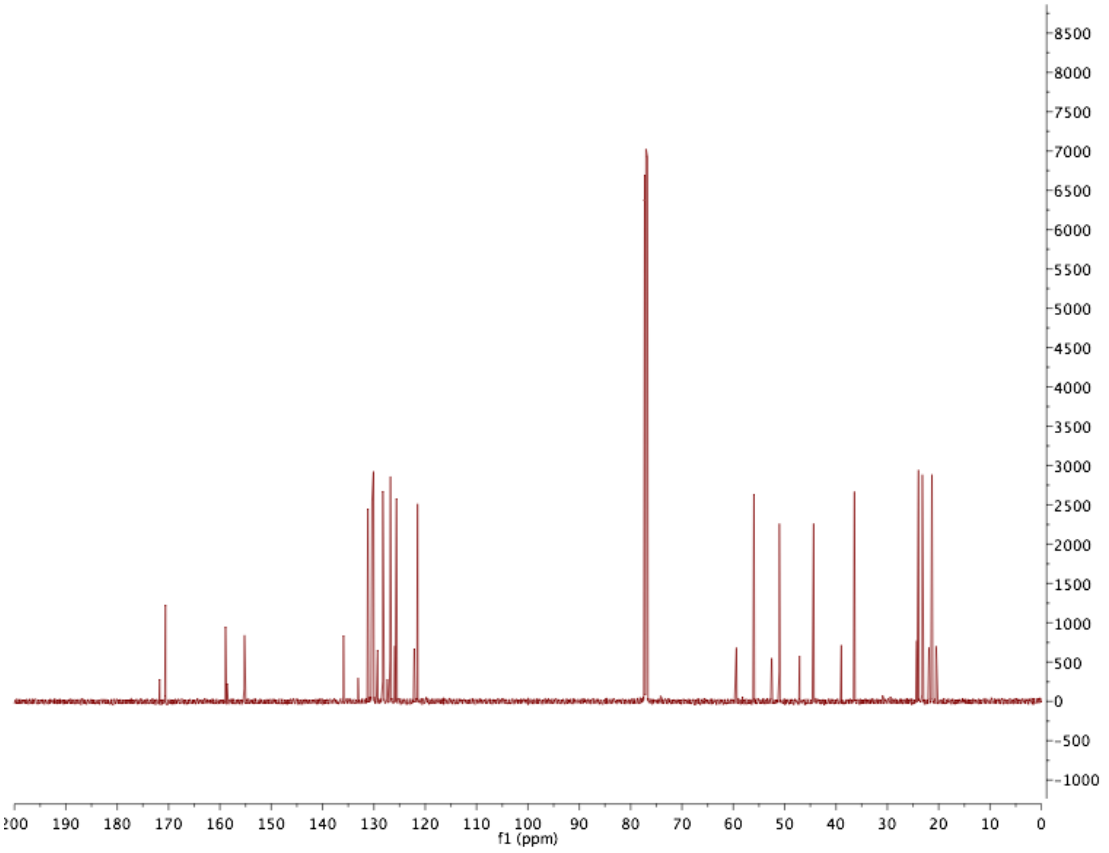

Br
O
O
S
O
O
O

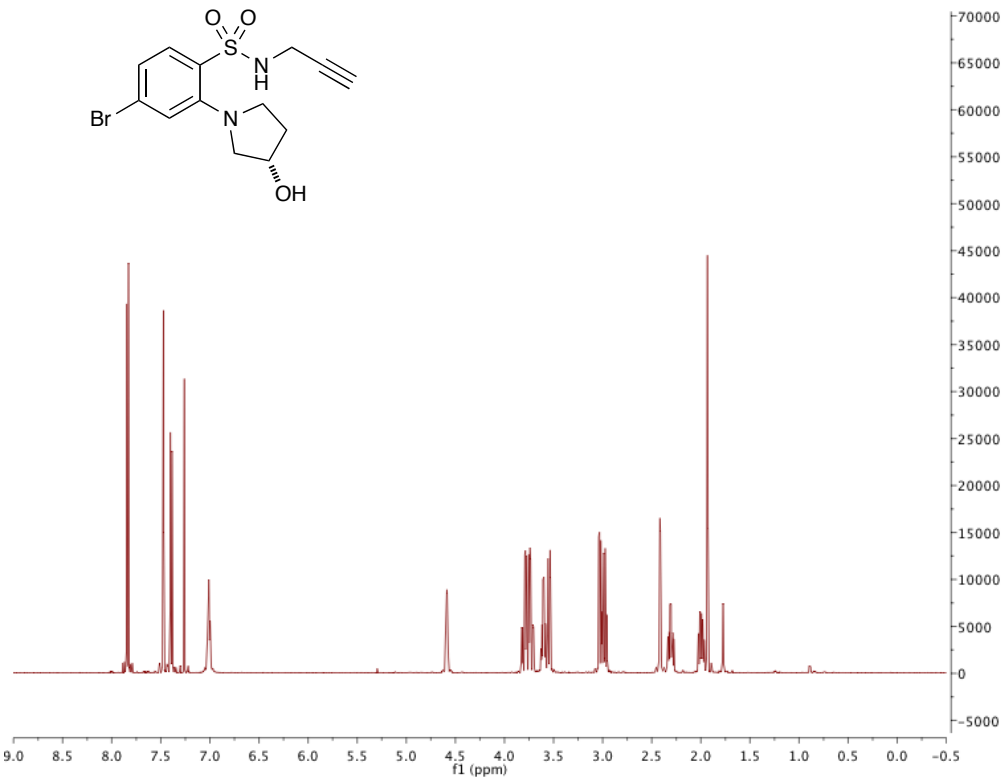
65000
60000
55000
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
-5000
8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)

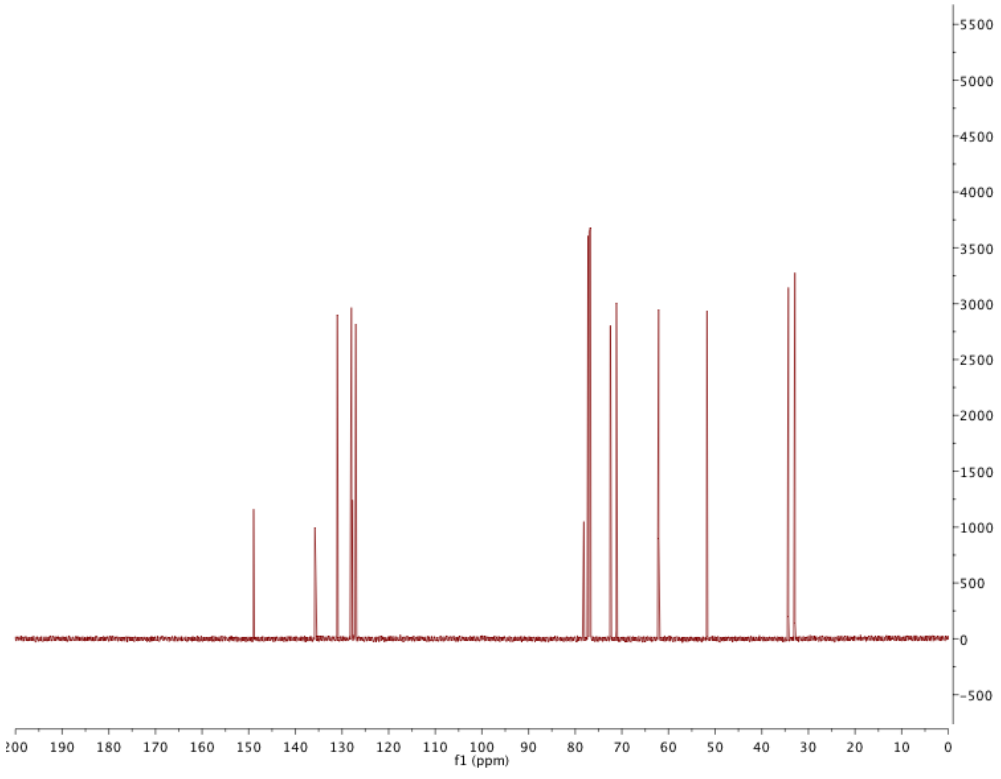

15000
14000
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
-1000
-2000
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

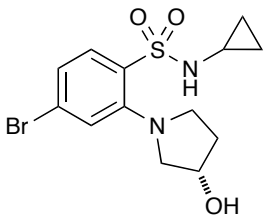

O
O
S
N
O
O
Br
O

80000
75000
70000
65000
60000
55000
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
-5000
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)

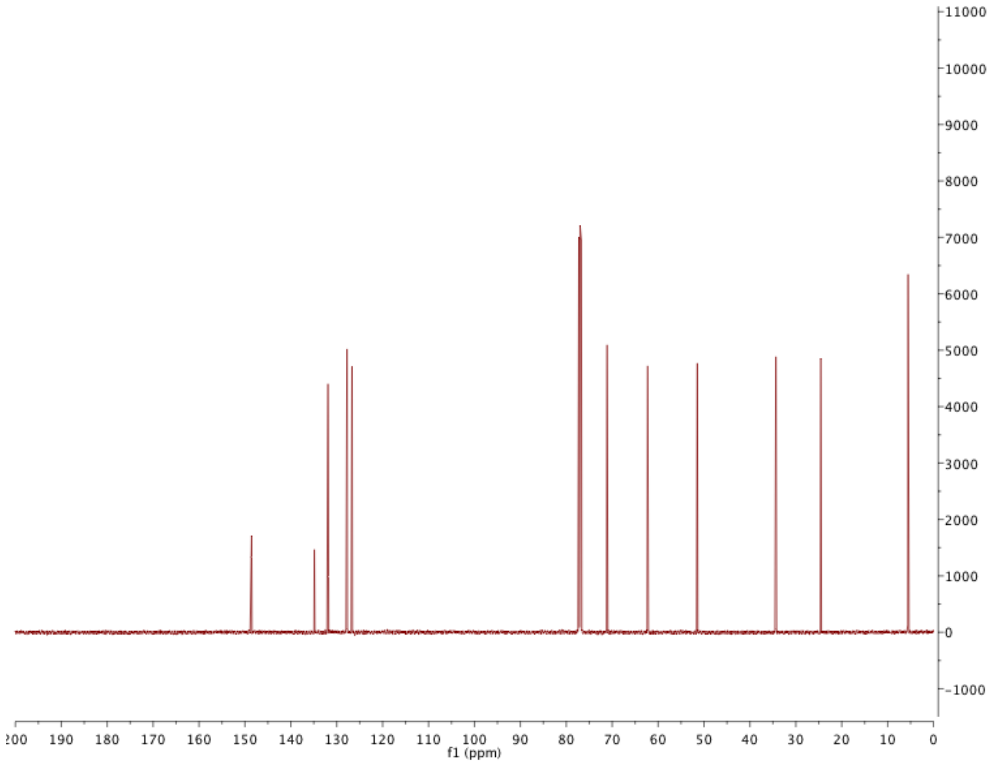

8500
8000
7500
7000
6500
6000
5500
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
-500
-1000
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

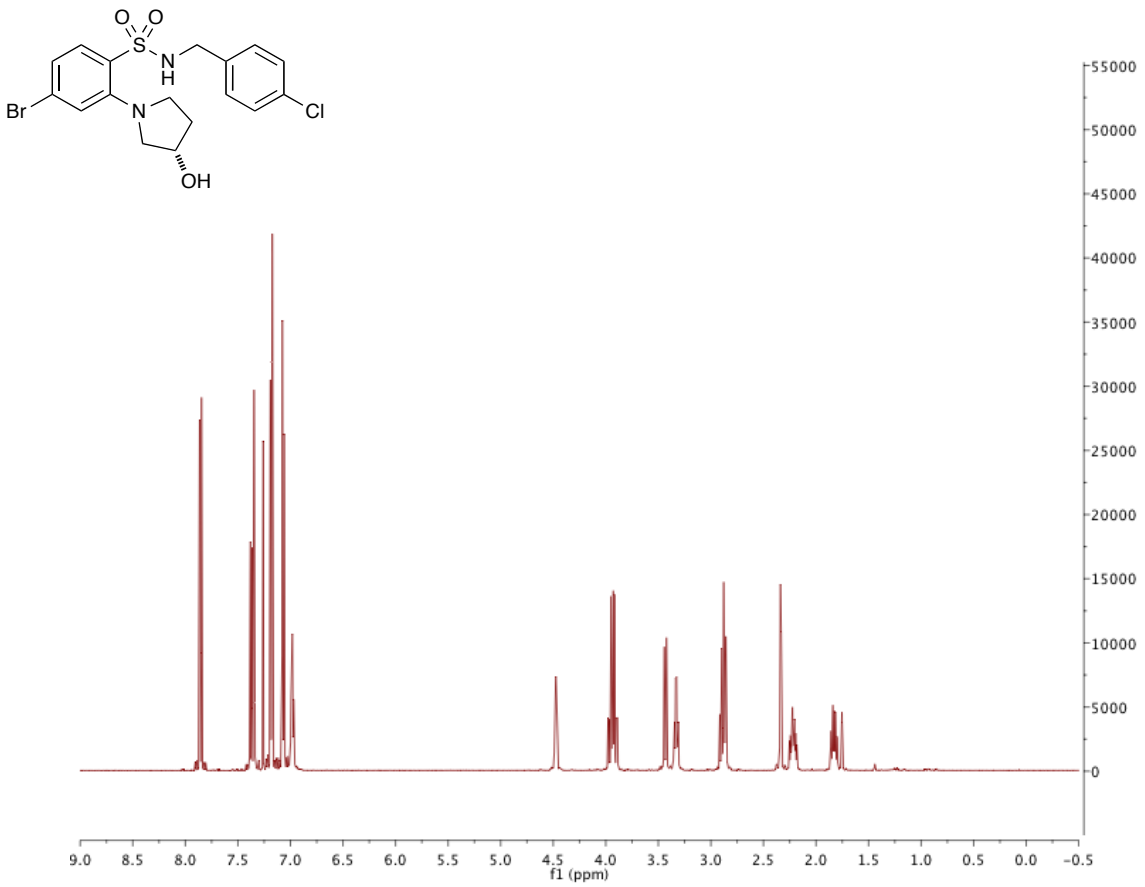

O
O
S
N
H
Br
N
OH
70000
65000
60000
55000
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
-5000
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)

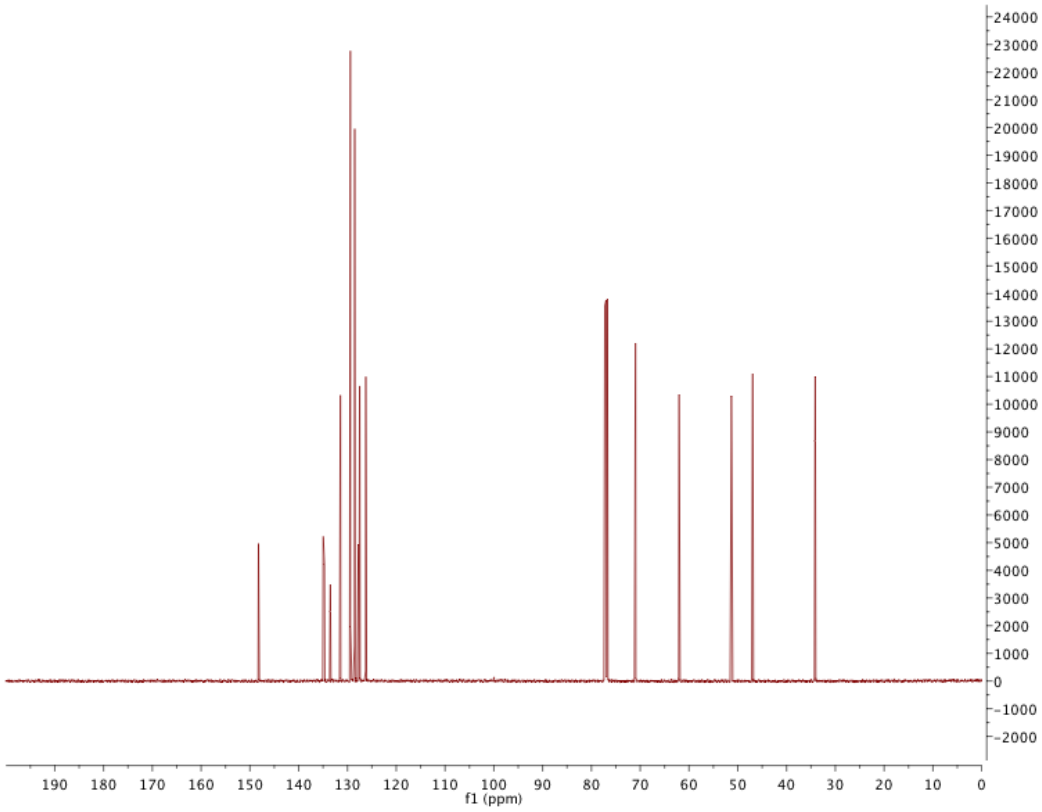

5500
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
-500
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

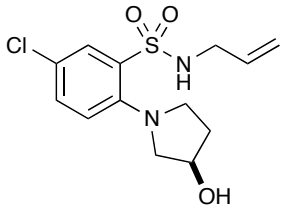

O
O
S
N
H
Br
N
OH

1E+05
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)

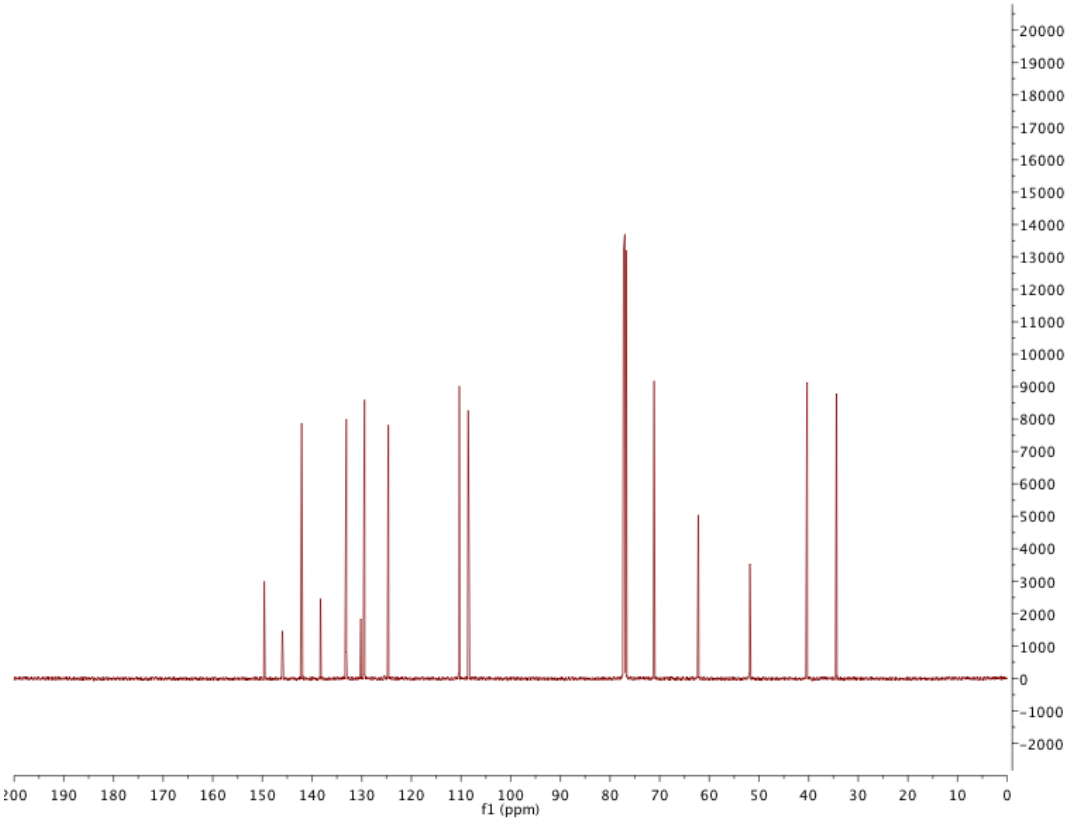

11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
-1000
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

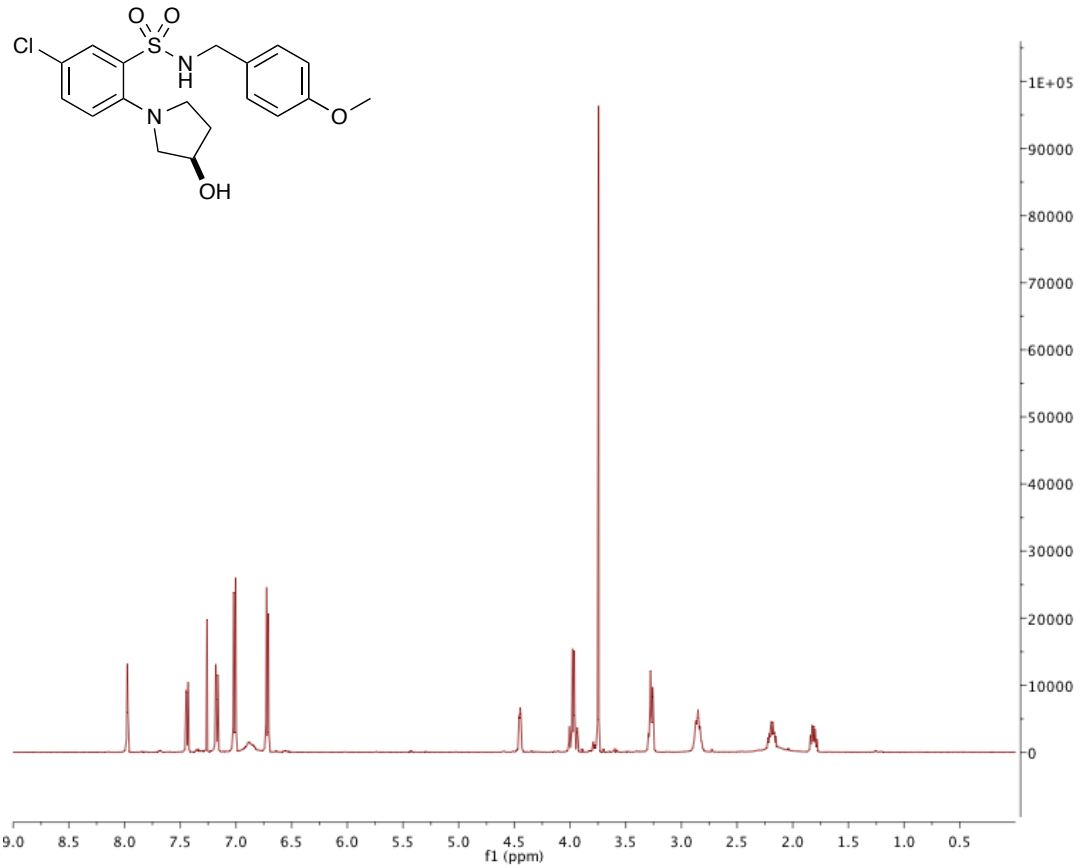

O
O
S
N
H
Br
N
Cl
OH
55000
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)

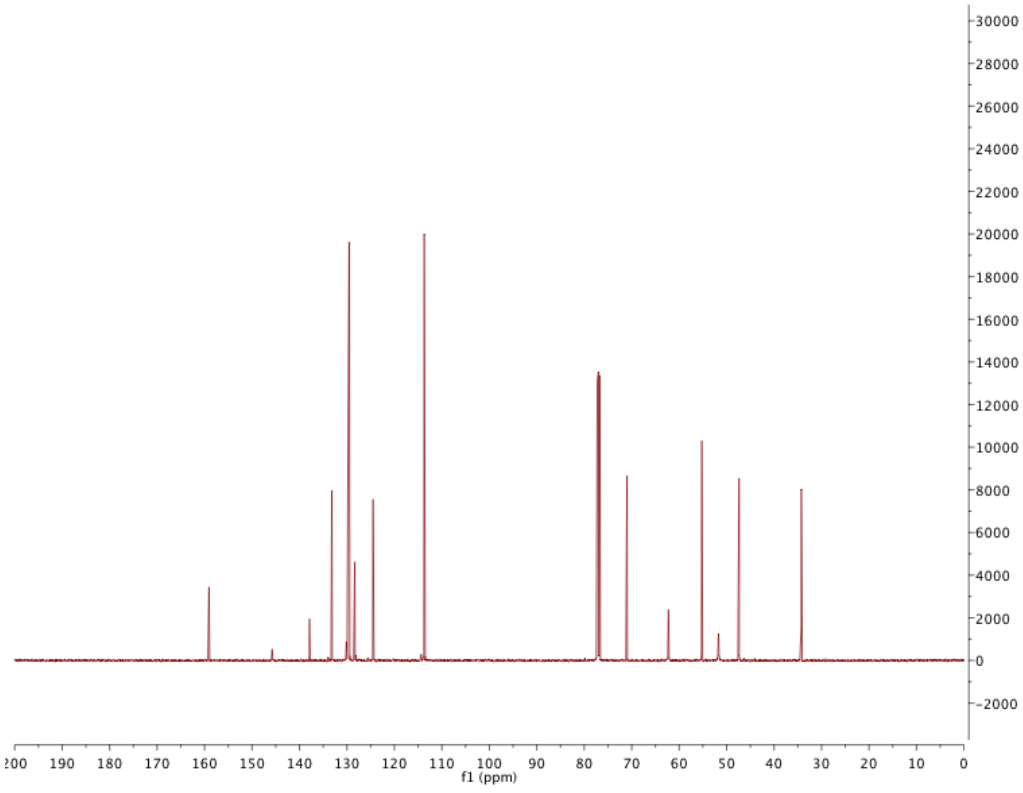

24000
23000
22000
21000
20000
19000
18000
17000
16000
15000
14000
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
-1000
-2000
190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

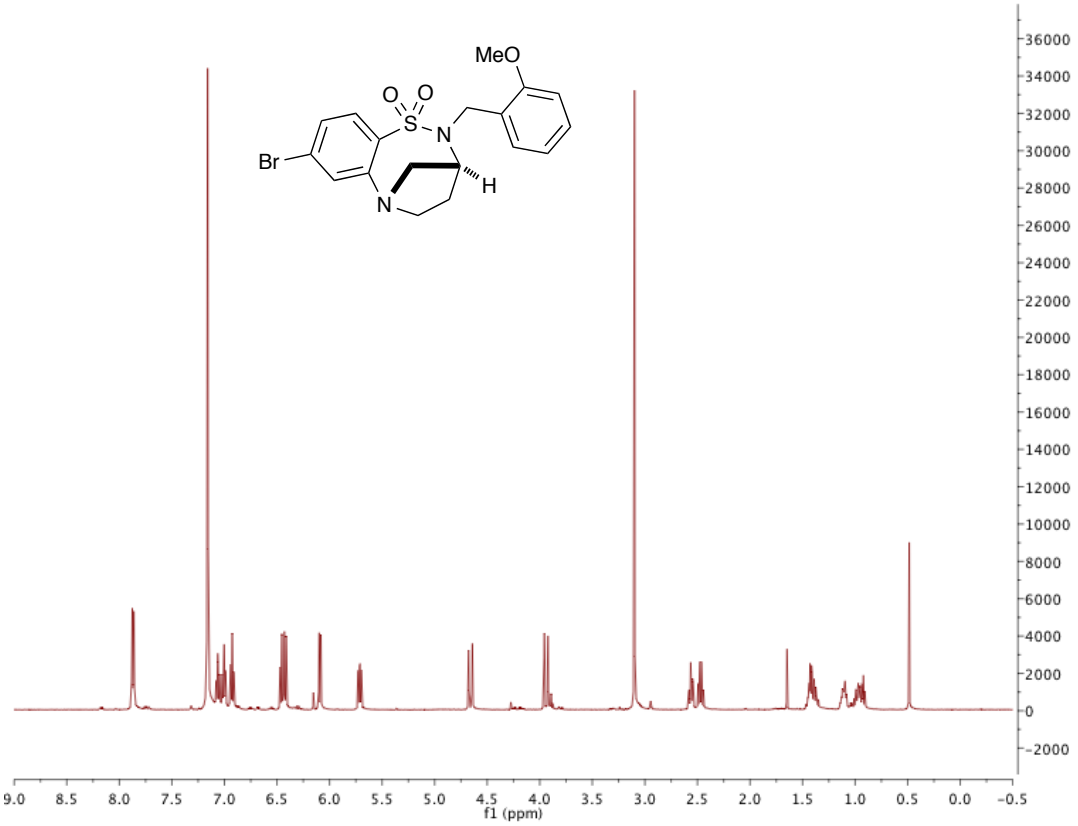

Cl
O
O
S
N
H
N
OH

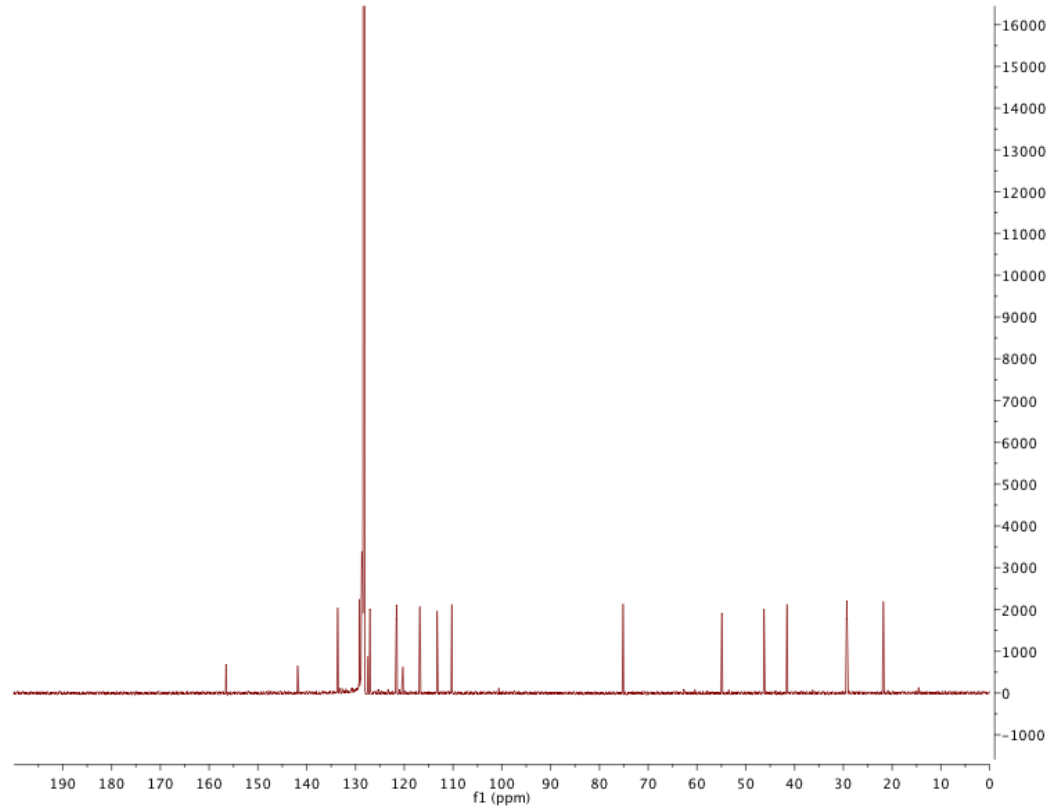
60000
55000
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
-5000
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)

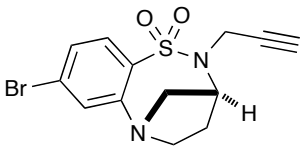

20000
19000
18000
17000
16000
15000
14000
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
-1000
-2000
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


Cl
O
O
S
N
H
N
O
OH
1E+05
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)

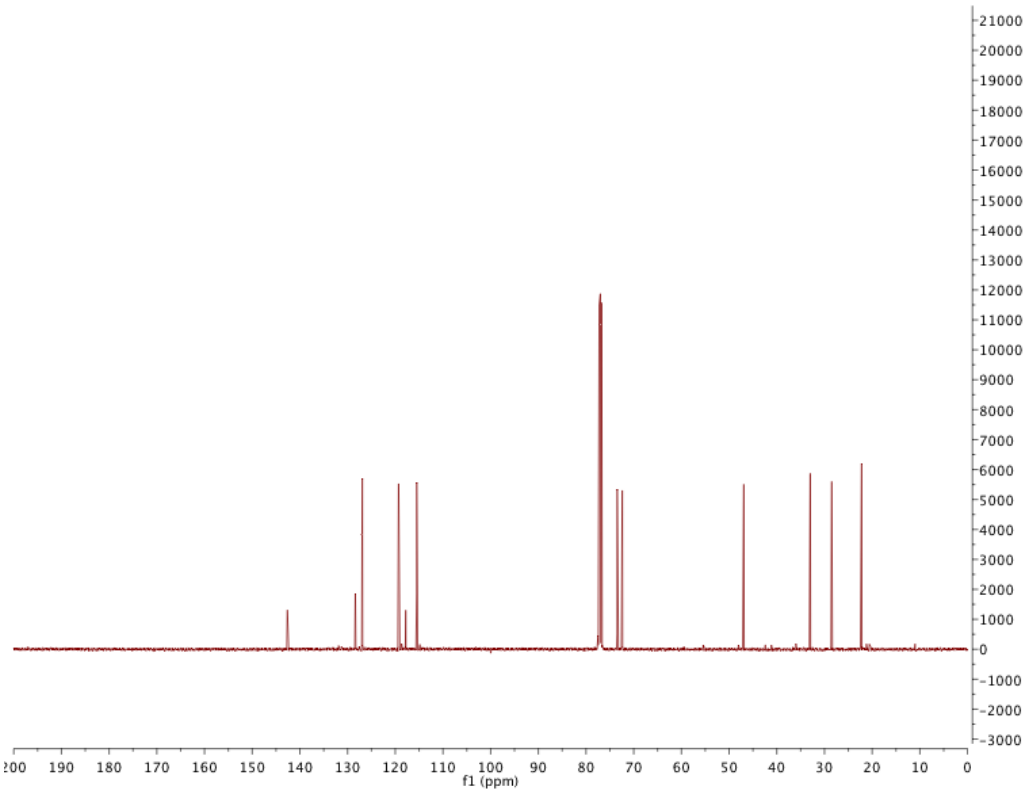

30000
28000
26000
24000
22000
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
-2000
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


MeO
O
O
S
N
Br
H
N
36000
34000
32000
30000
28000
26000
24000
22000
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
-2000
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)


16000
15000
14000
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
-1000
190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


O
O
S
N
Br
H
N

65000
60000
55000
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
-5000
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)


21000
20000
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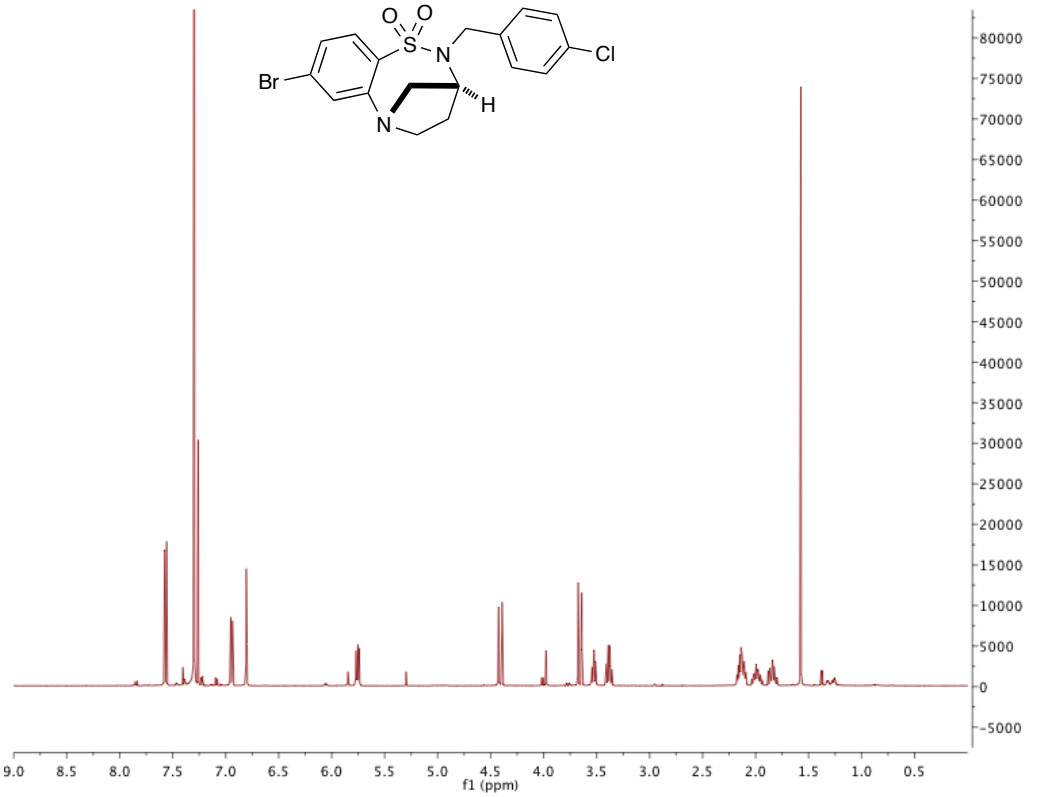
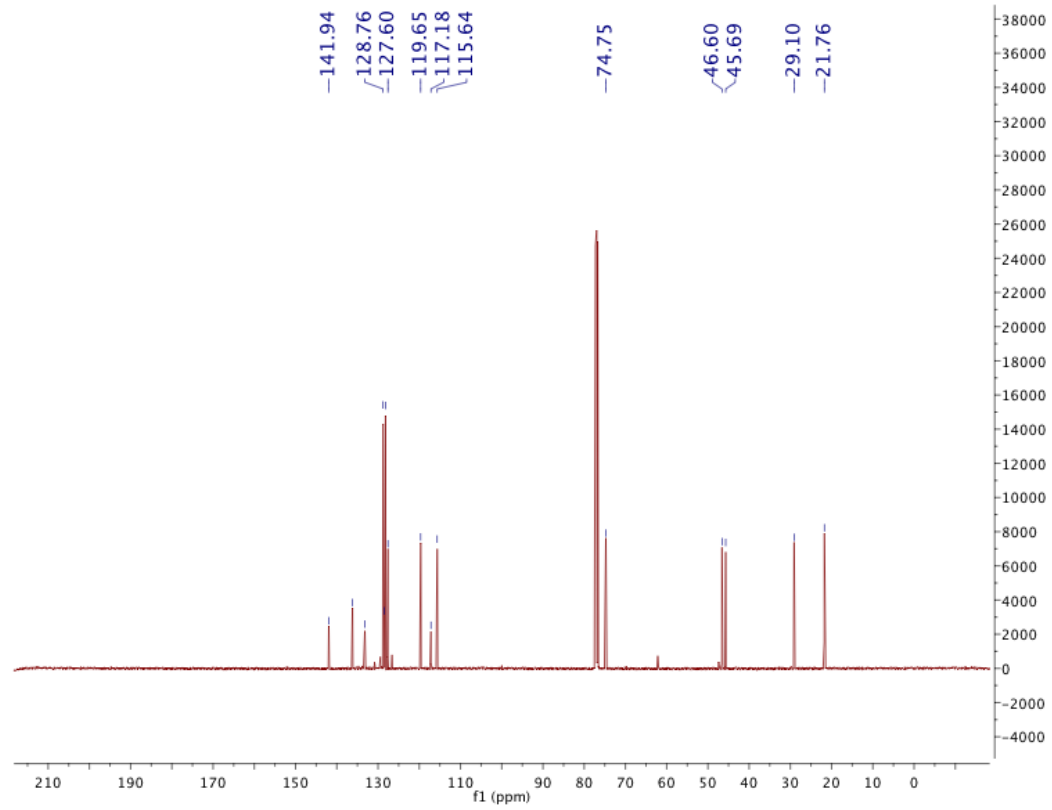
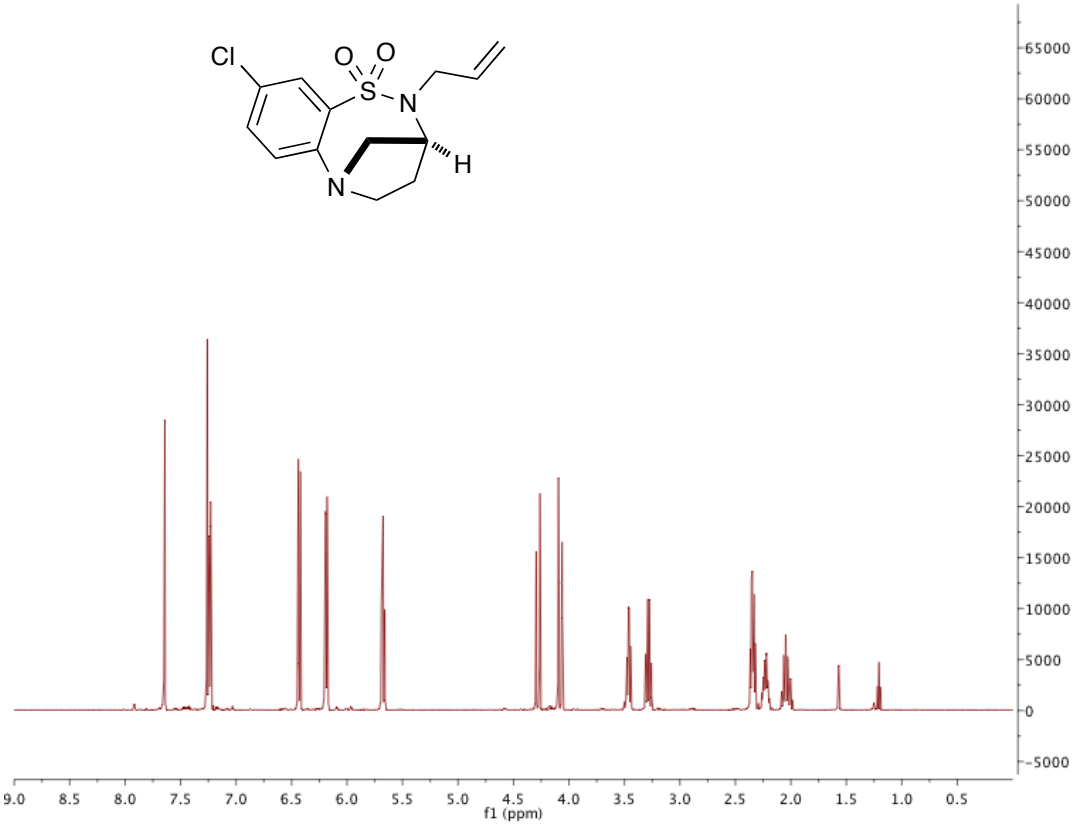
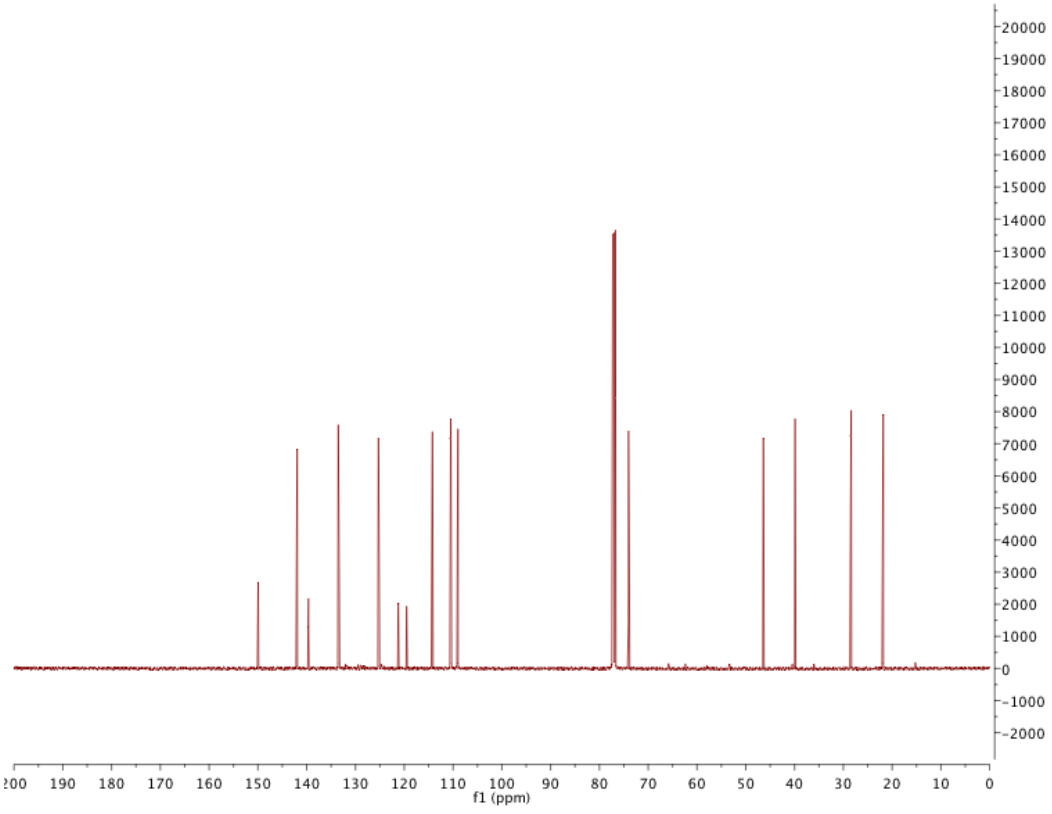
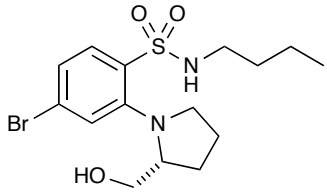
17000
16000
15000
14000
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
-1000
-2000
-3000
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


O
O
S
N
Br
Cl
H
N
80000
75000
70000
65000
60000
55000
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
-5000
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)

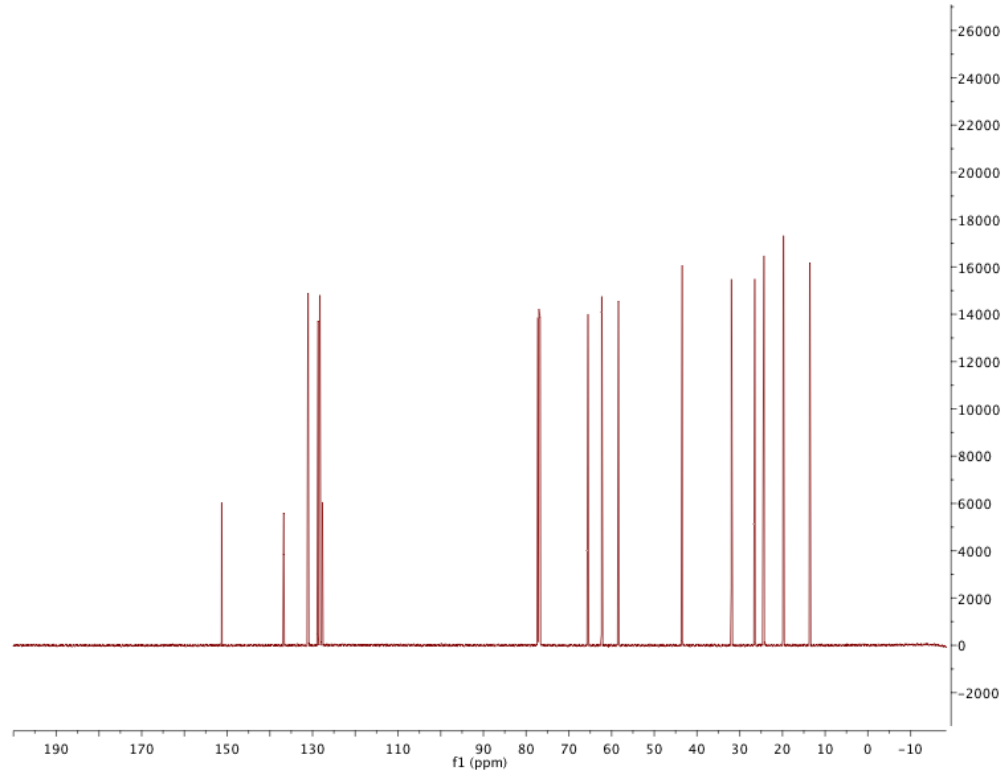

141.94
128.76
127.60
119.65
117.18
115.64
74.75
46.60
45.69
29.10
21.76
38000
36000
34000
32000
30000
28000
26000
24000
22000
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
-2000
-4000
210
190
170
150
130
110
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

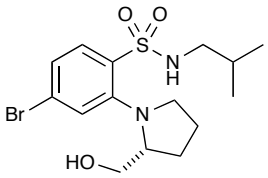

Cl
O
O
S
N
H
N
65000
60000
55000
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
-5000
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
f1 (ppm)


20000
19000
18000
17000
16000
15000
14000
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
-1000
-2000
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

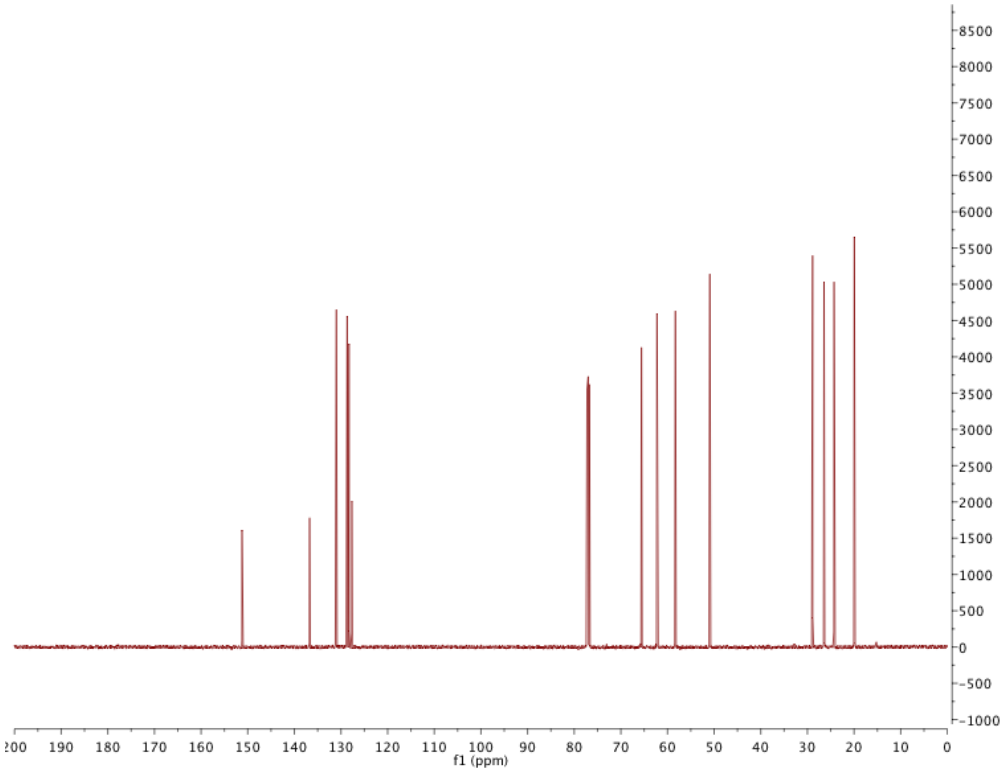

O
O
S
N
H
Br
N
HO

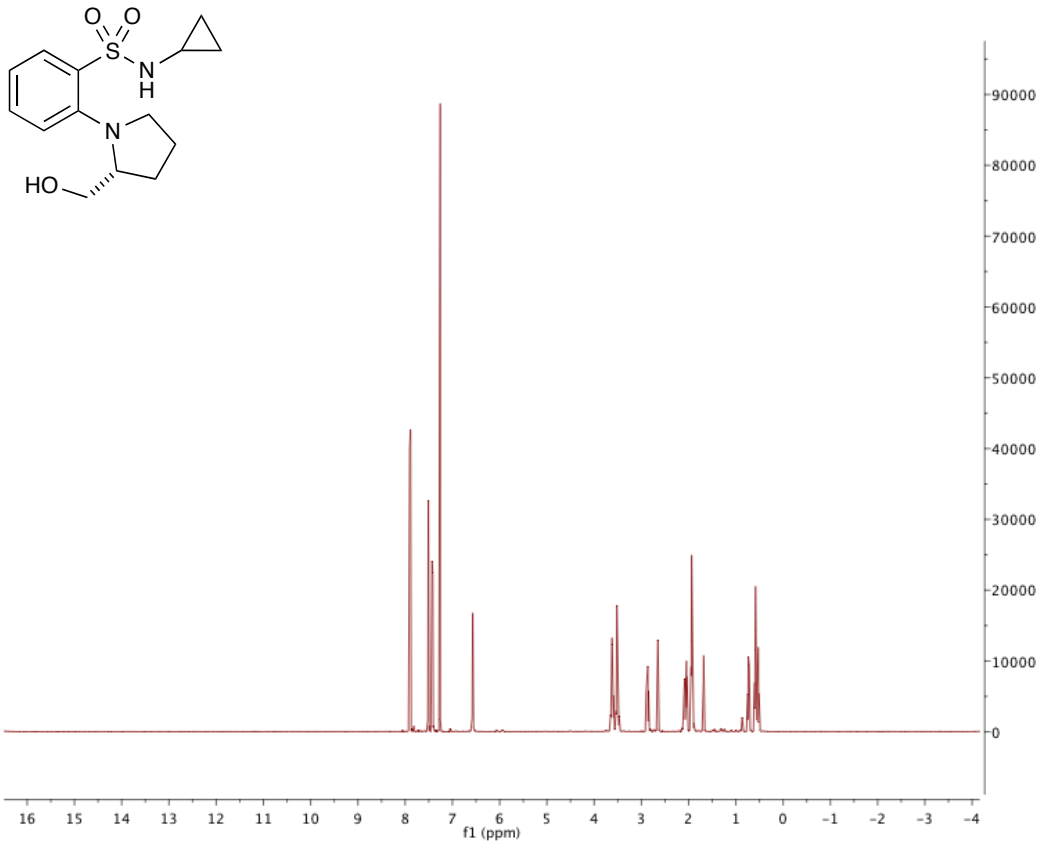
70000
65000
60000
55000
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
-5000
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)

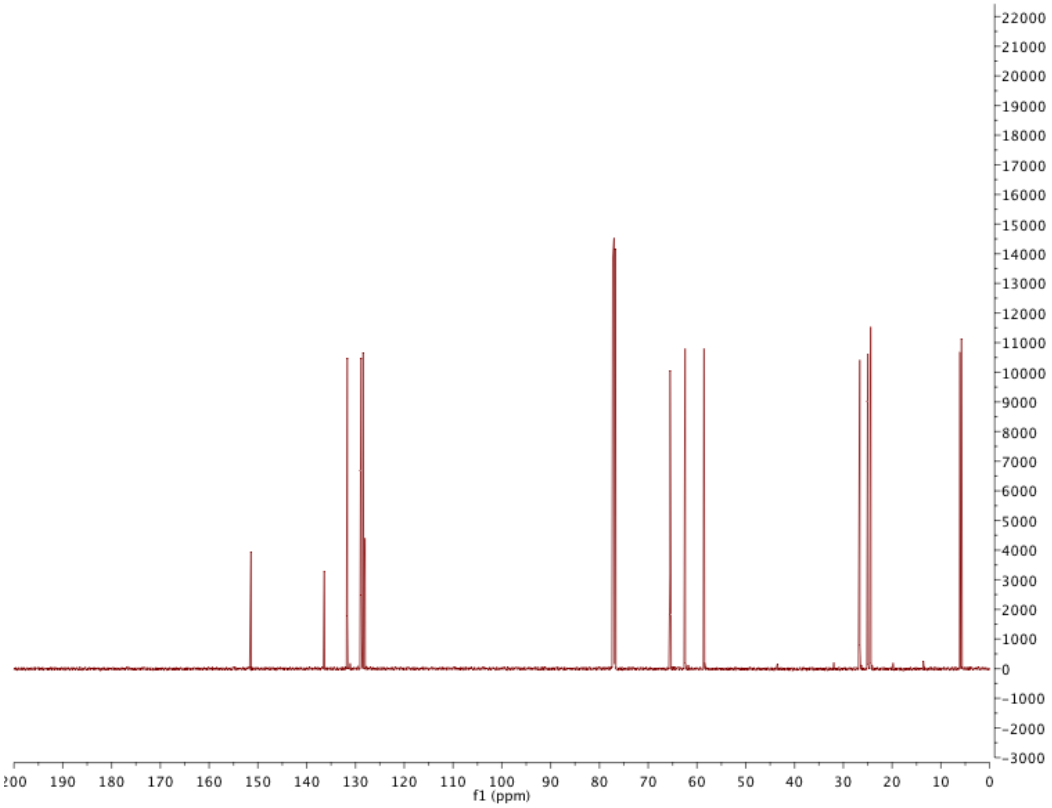

26000
24000
22000
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
-2000
190 170 150 130 110 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

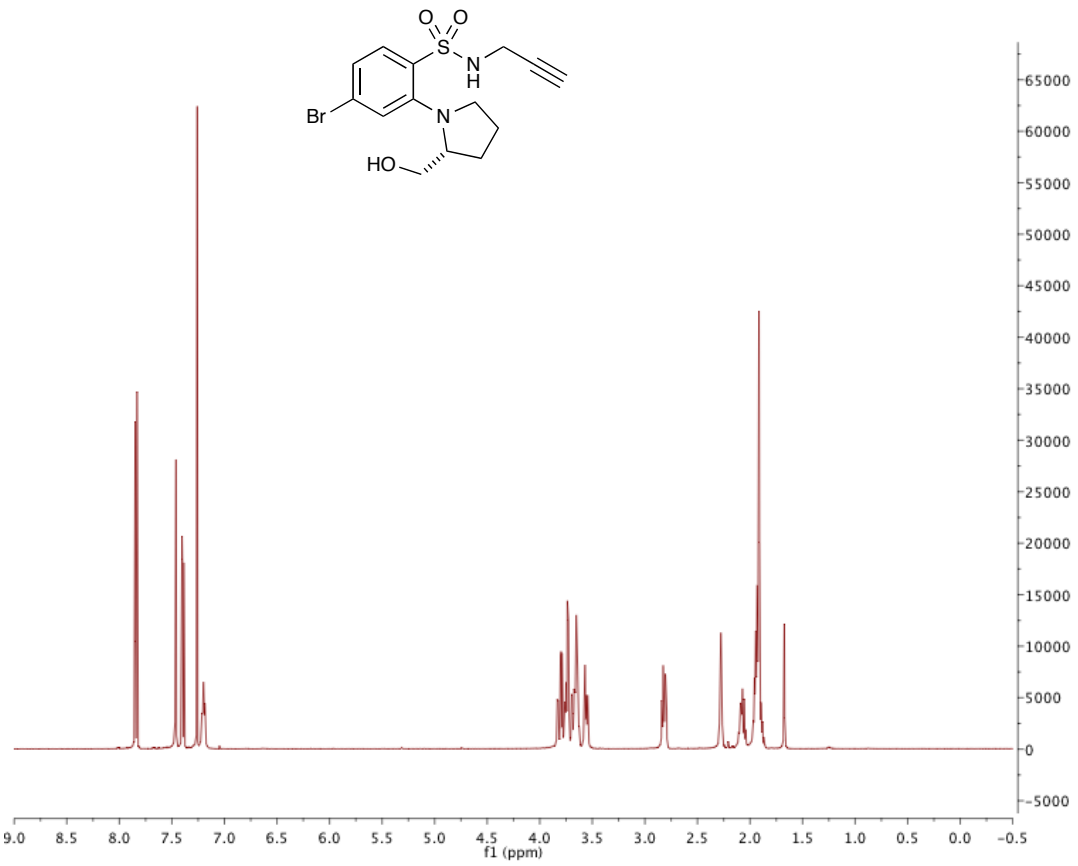

O
O
S
N
H
Br
N
HO

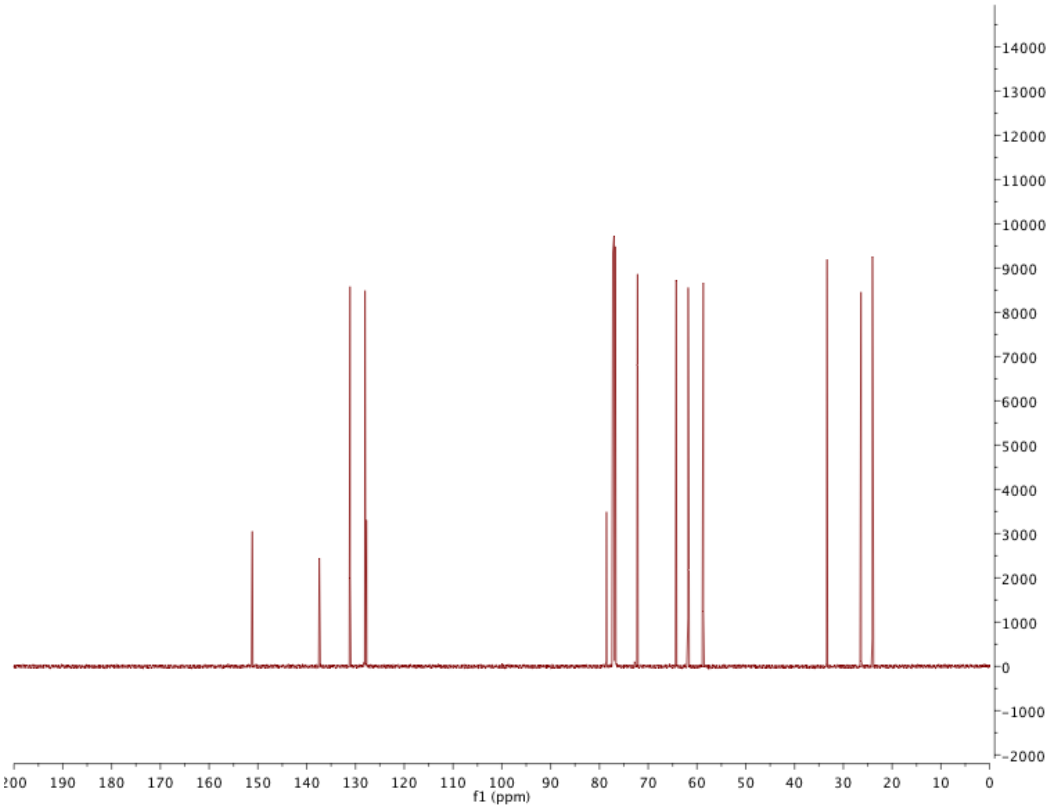
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)

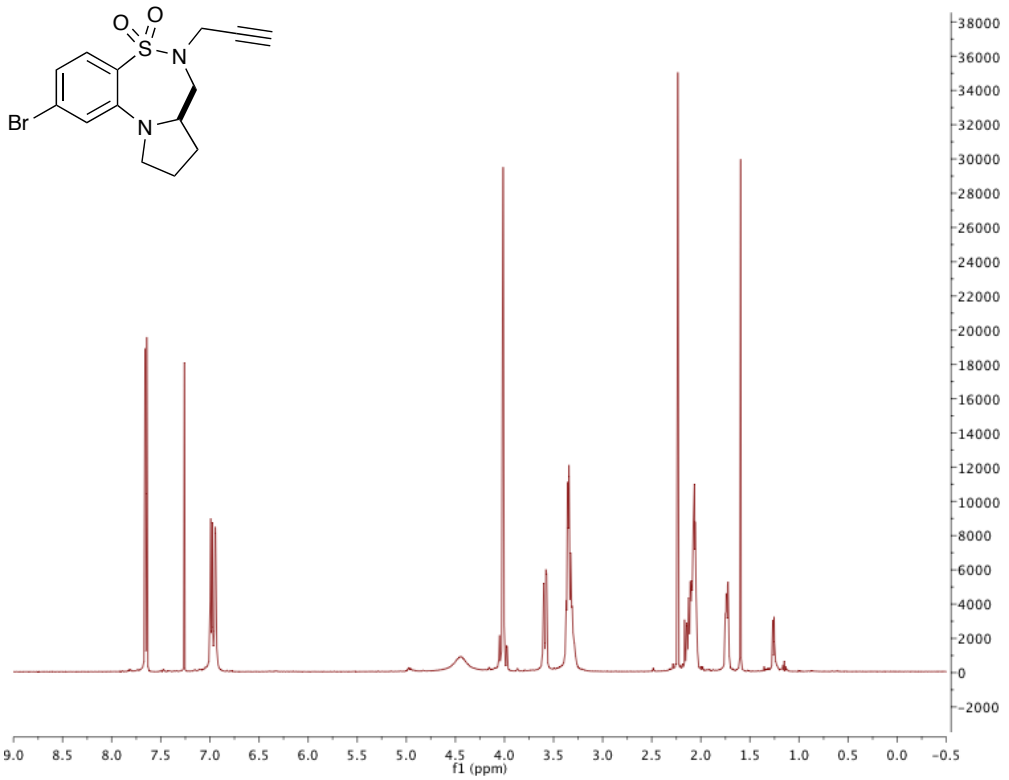

8500
8000
7500
7000
6500
6000
5500
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
-500
-1000
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

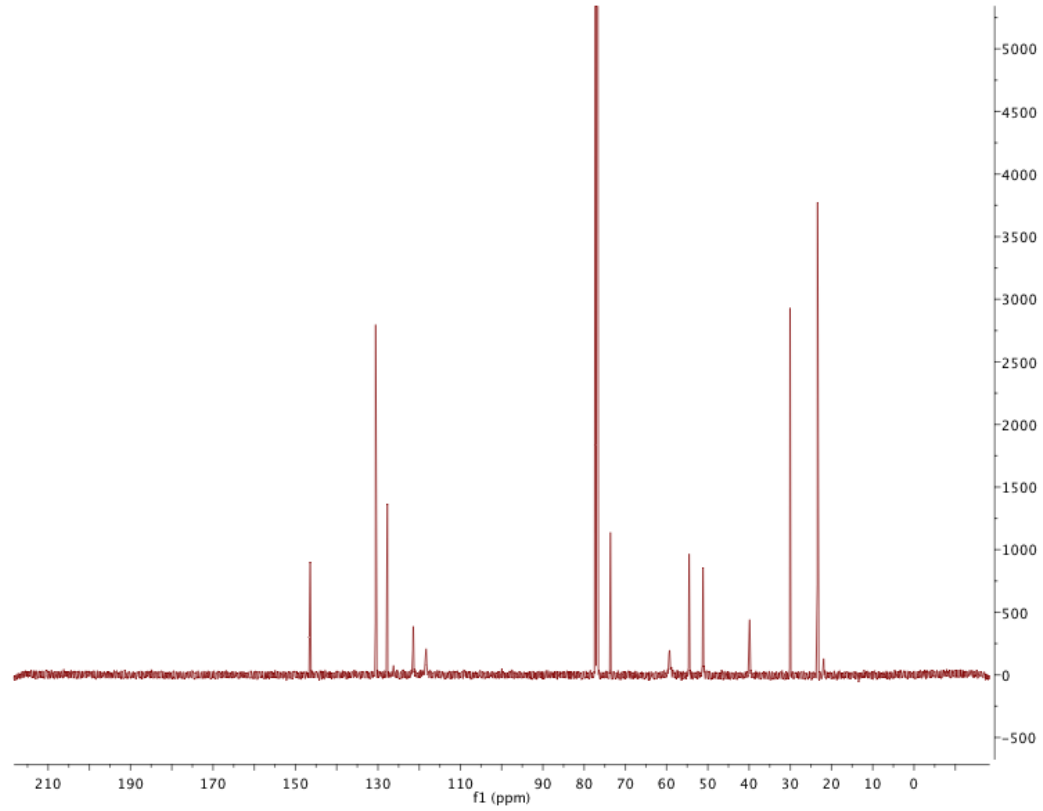

O
O
S
N
H
N
HO
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 −1 −2 −3 −4
f1 (ppm)

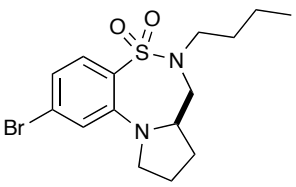

22000
21000
20000
19000
18000
17000
16000
15000
14000
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
−1000
−2000
−3000
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


O
O
S
N
H
Br
N
HO
65000
60000
55000
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
-5000
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)

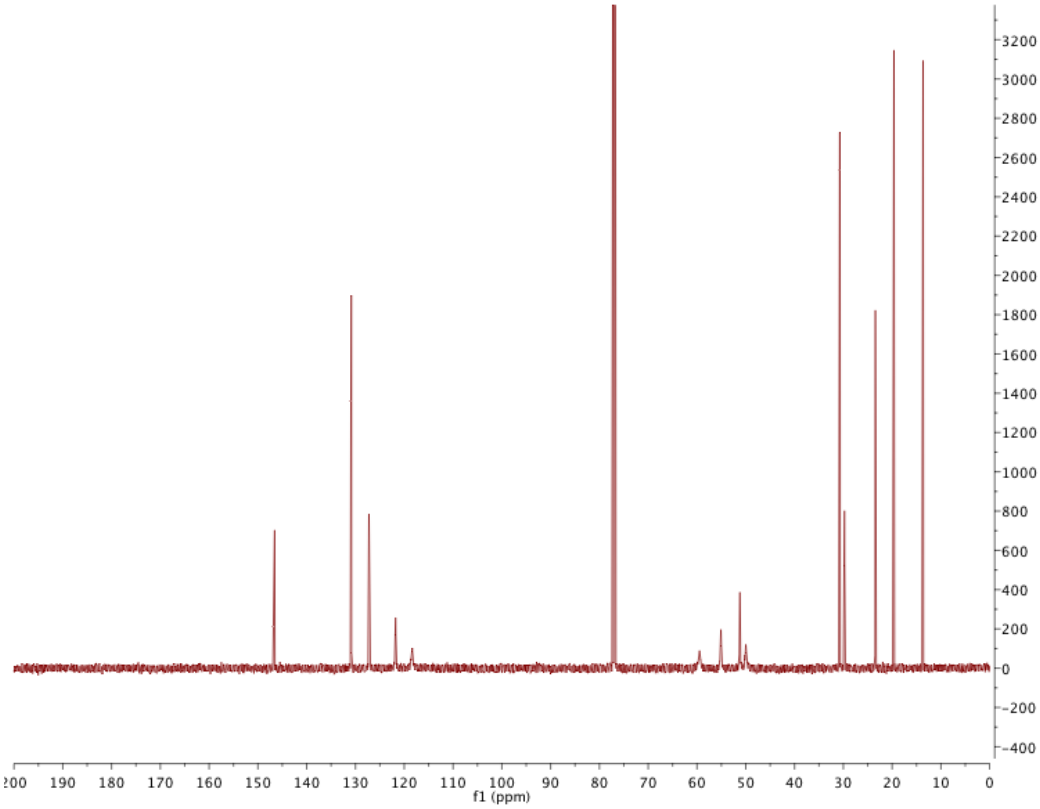

14000
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
-1000
-2000
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

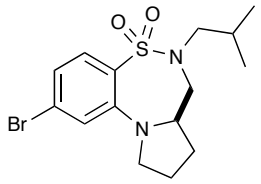

O
O
S
N
Br
N
38000
36000
34000
32000
30000
28000
26000
24000
22000
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
-2000
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)

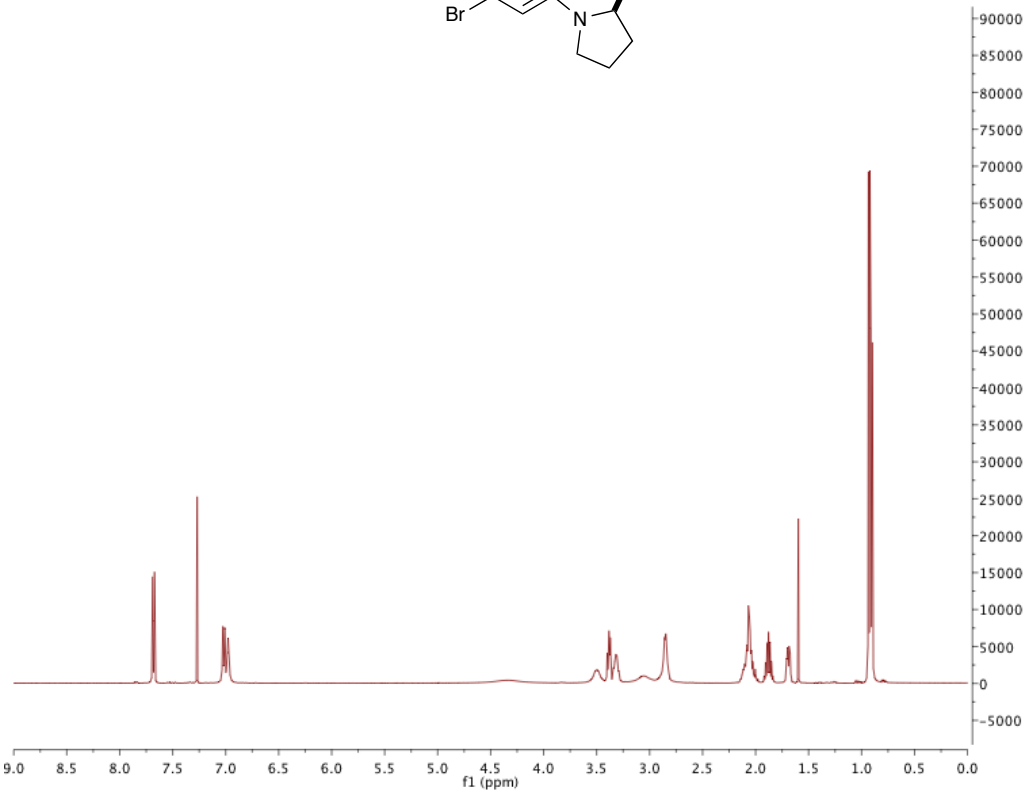

5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
-500
210 190 170 150 130 110 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


O
O
S
N
Br
N

40000
35000
30000
25000
20000
15000
10000
5000
0
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)


3200
3000
2800
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
-200
-400
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


O
O
S
N
Br
N


90000
85000
80000
75000
70000
65000
60000
55000
50000
45000
40000
35000
30000
25000
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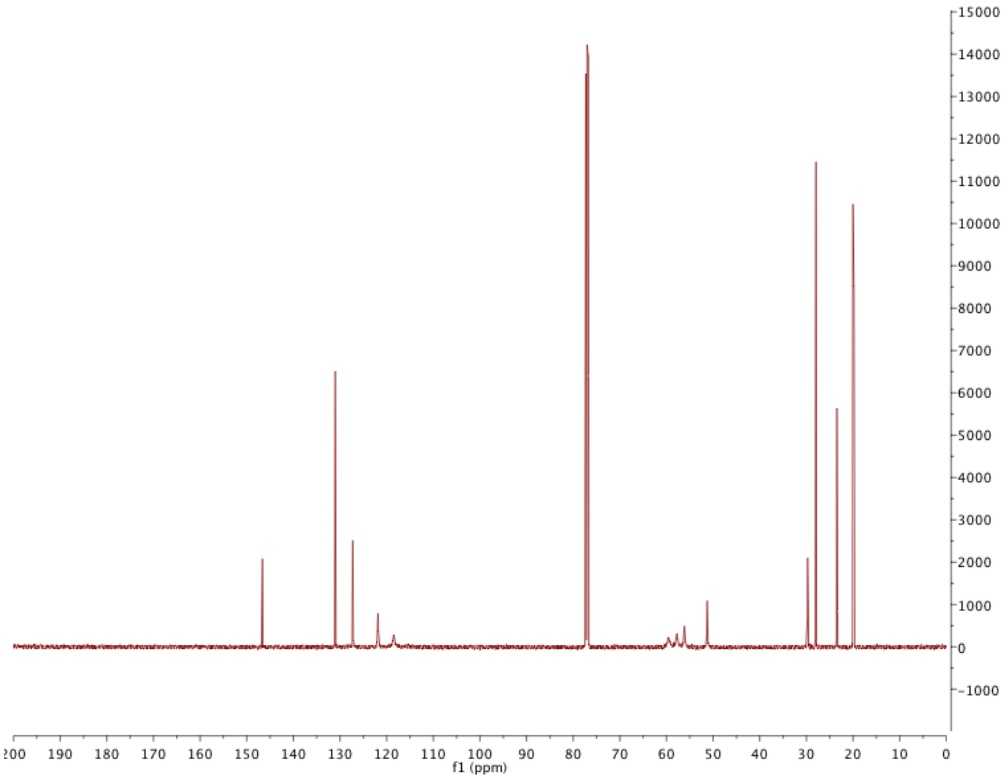
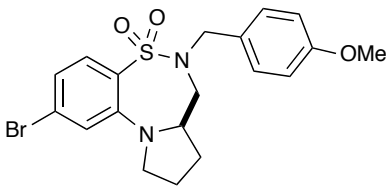
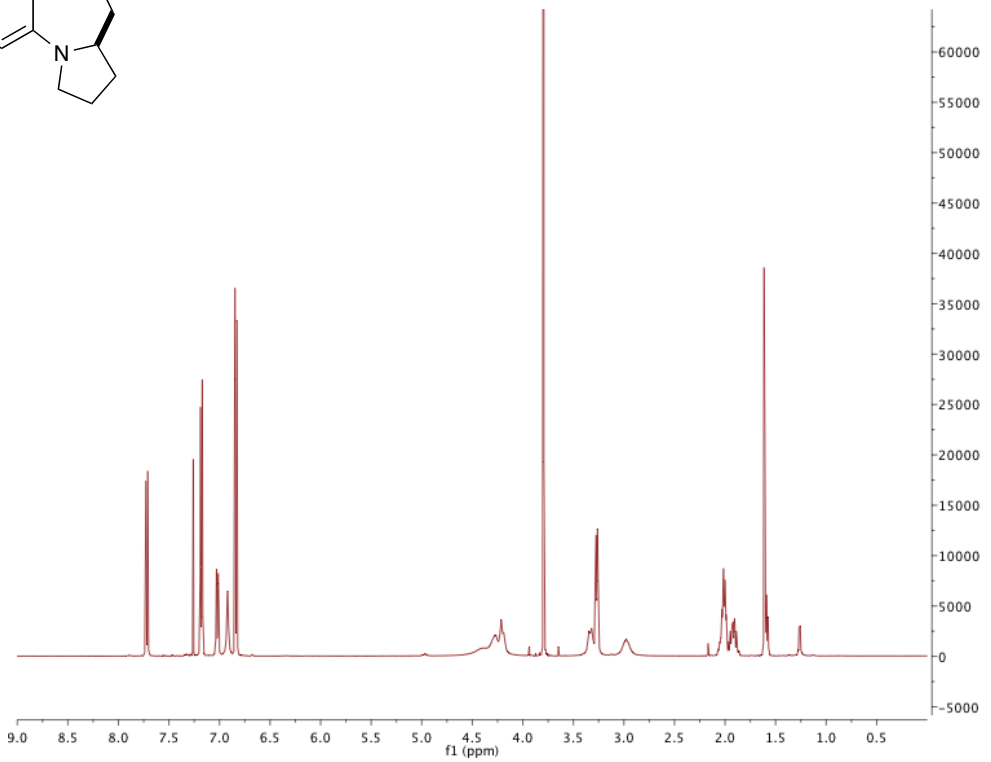
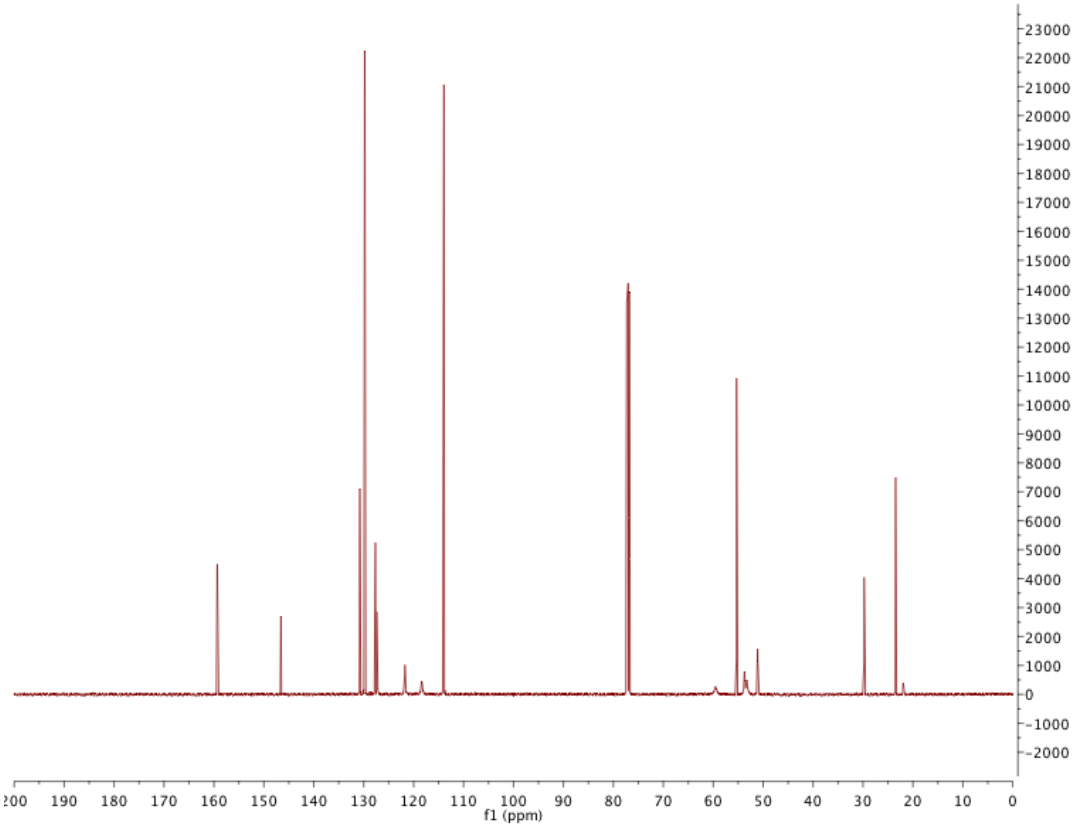
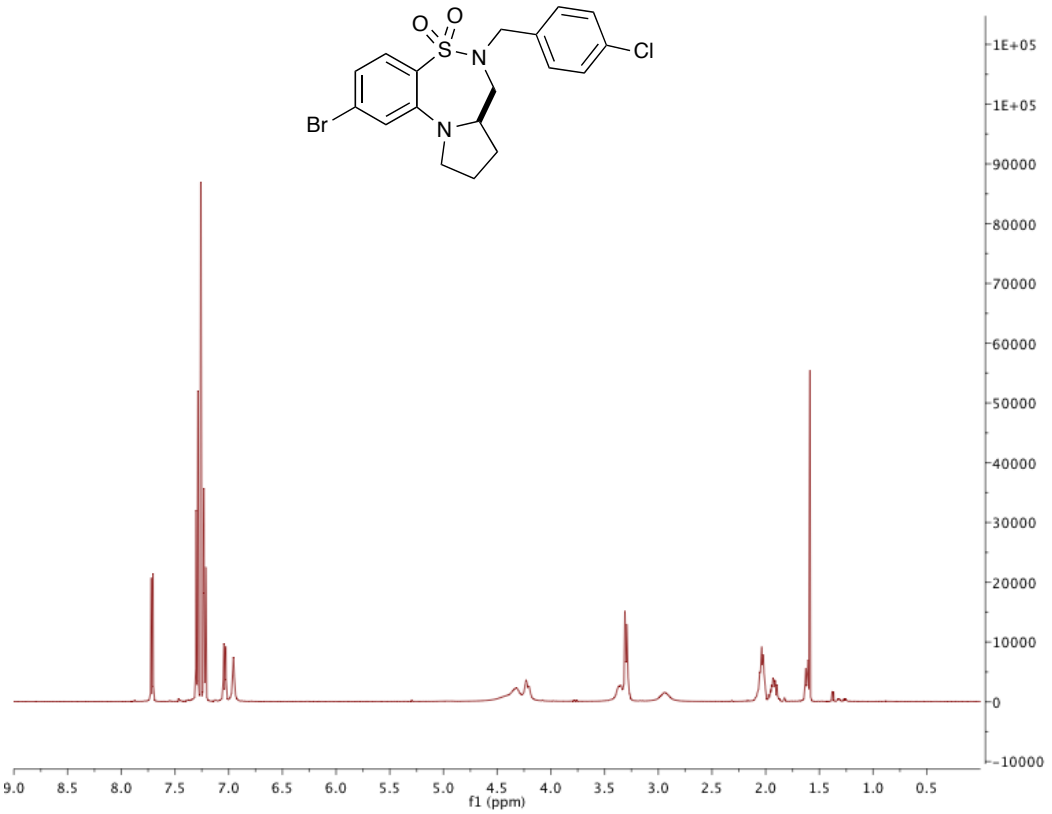
15000
10000
5000
0
-5000
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

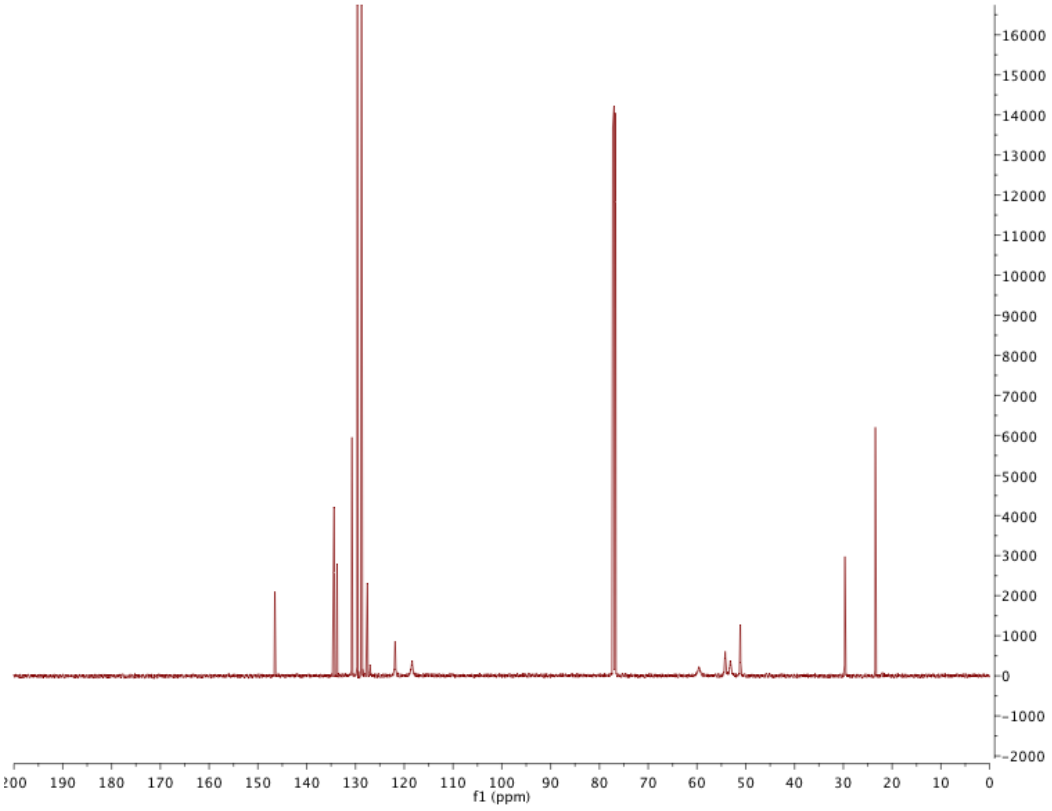

15000
14000
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
-1000
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

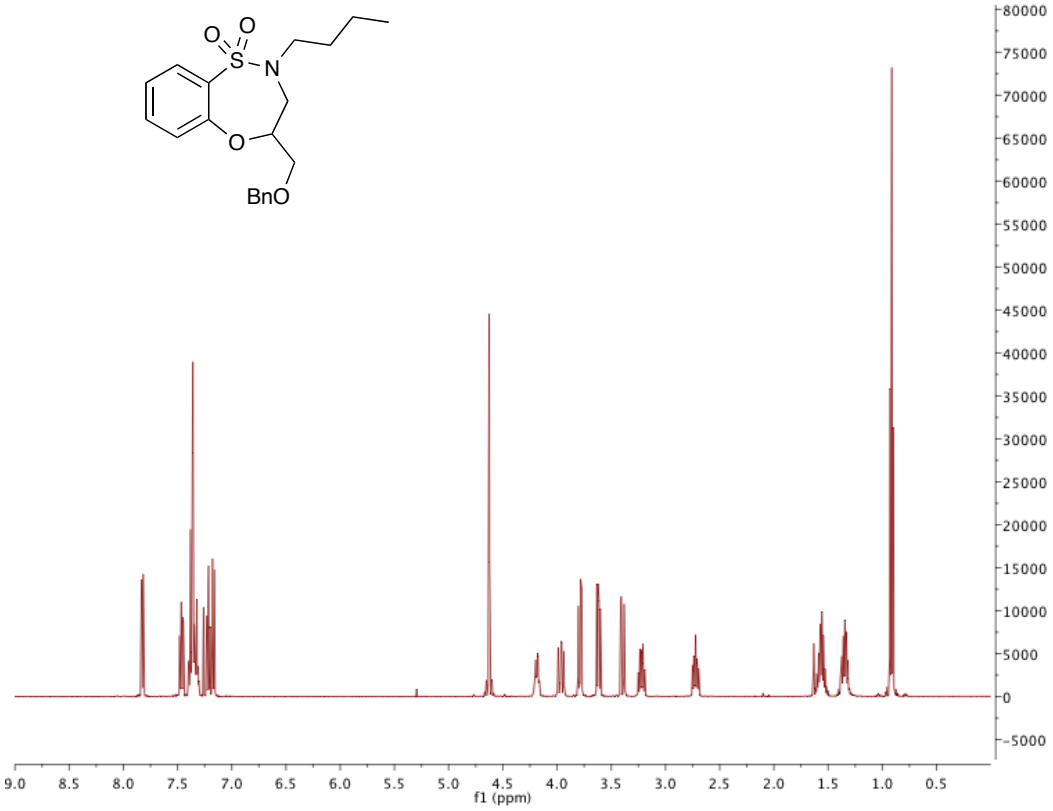

O
O
S
N
OMe
Br
N

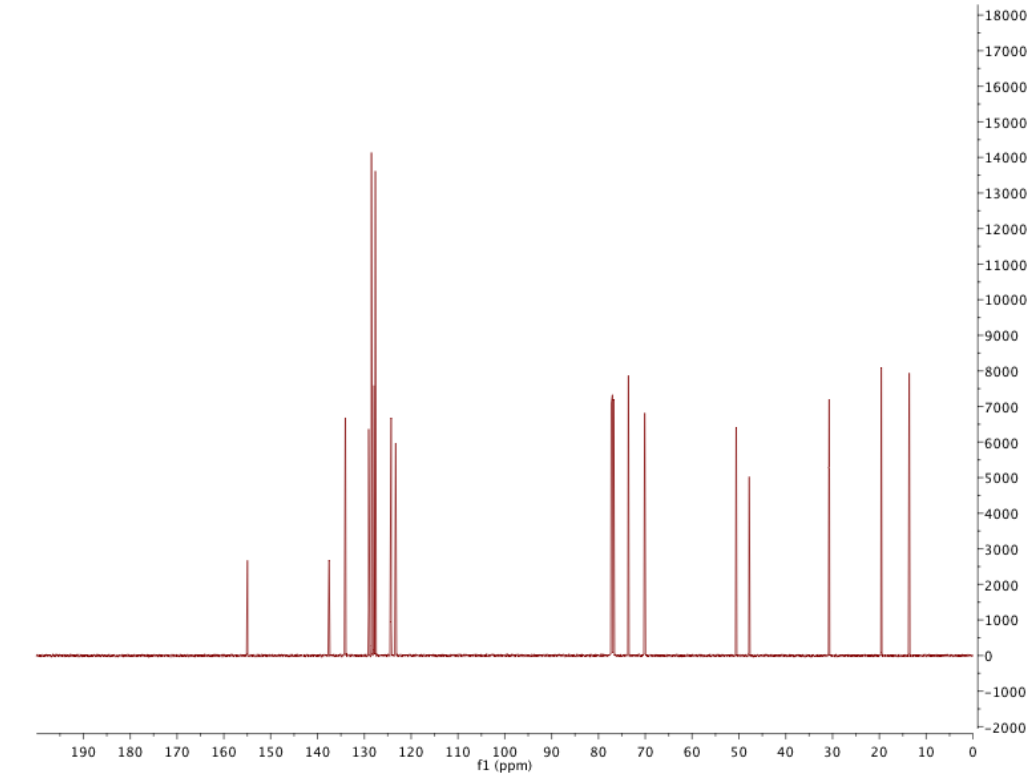

60000
55000
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
-5000
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
f1 (ppm)


23000
22000
21000
20000
19000
18000
17000
16000
15000
14000
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
-1000
-2000
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


O
O
S
N
Cl
Br
N
1E+05
1E+05
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
-10000
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
f1 (ppm)


16000
15000
14000
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
-1000
-2000
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


O
O
S
N
O
BnO
80000
75000
70000
65000
60000
55000
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
-5000
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
f1 (ppm)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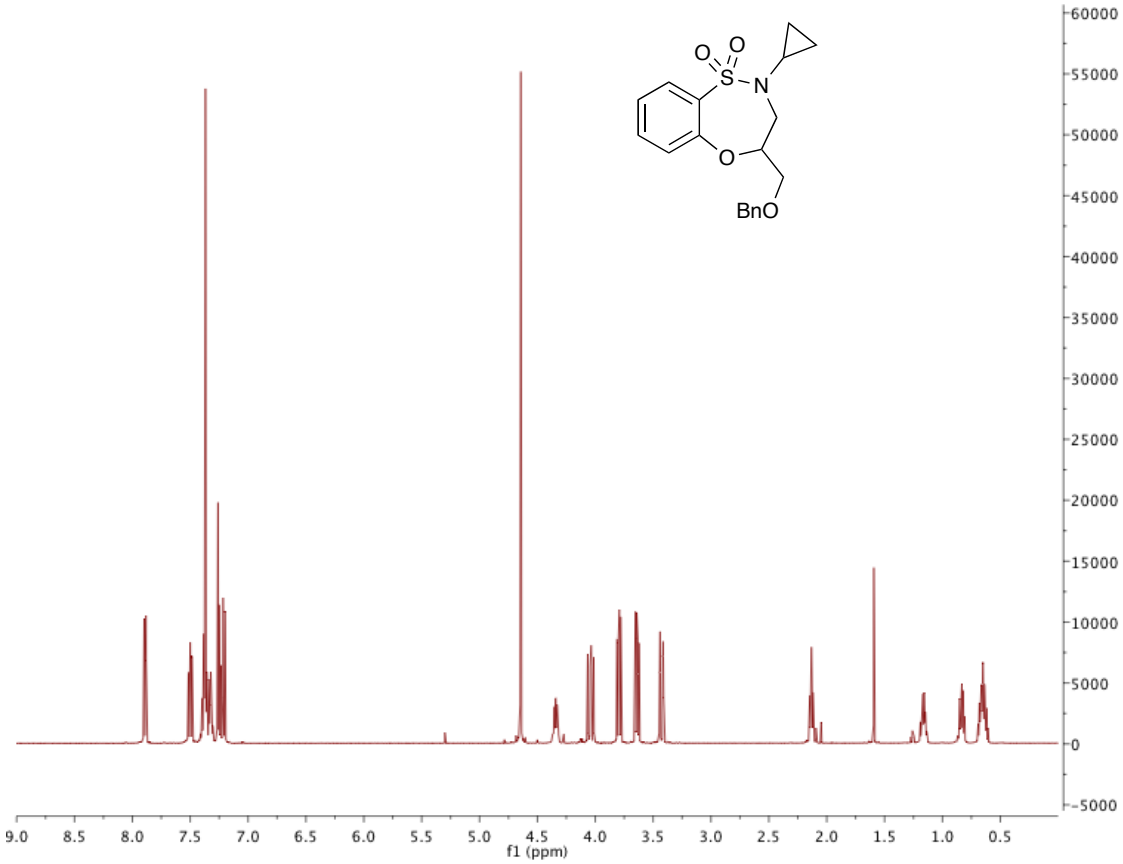
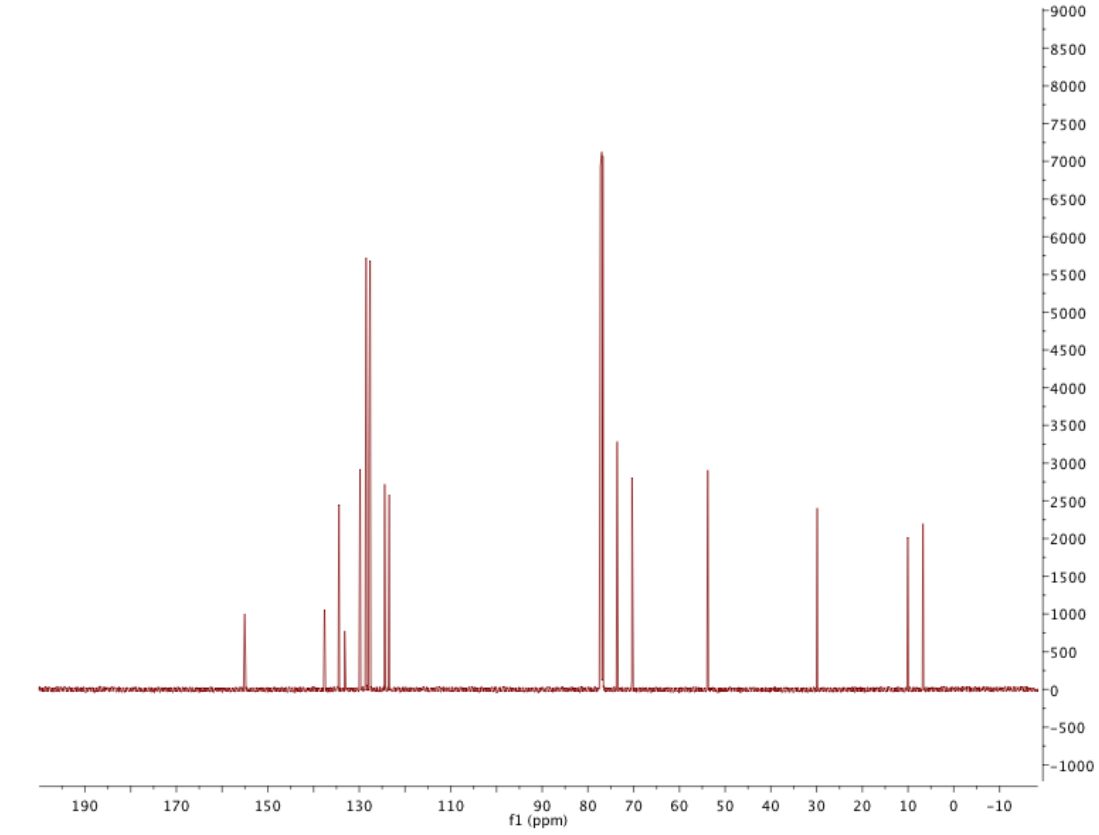
17000
16000
15000
14000
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
-1000
-2000
190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


O
O
S
N
O
BnO
60000
55000
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
-5000
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)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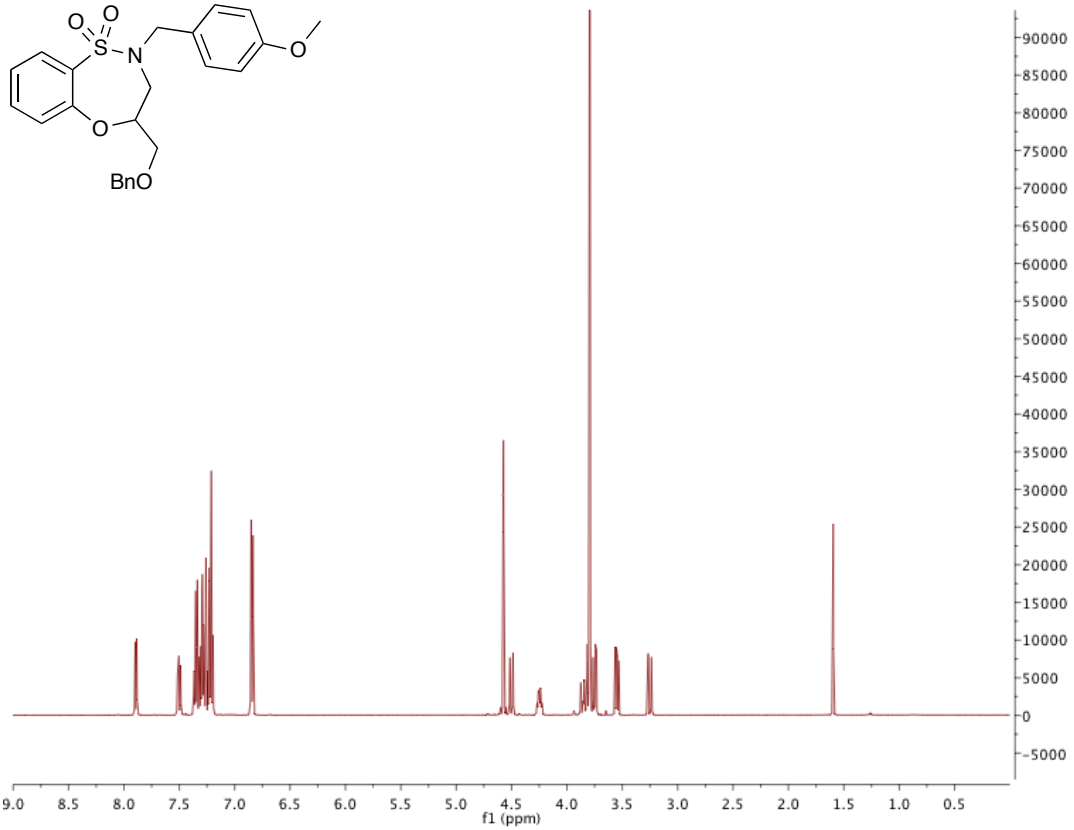
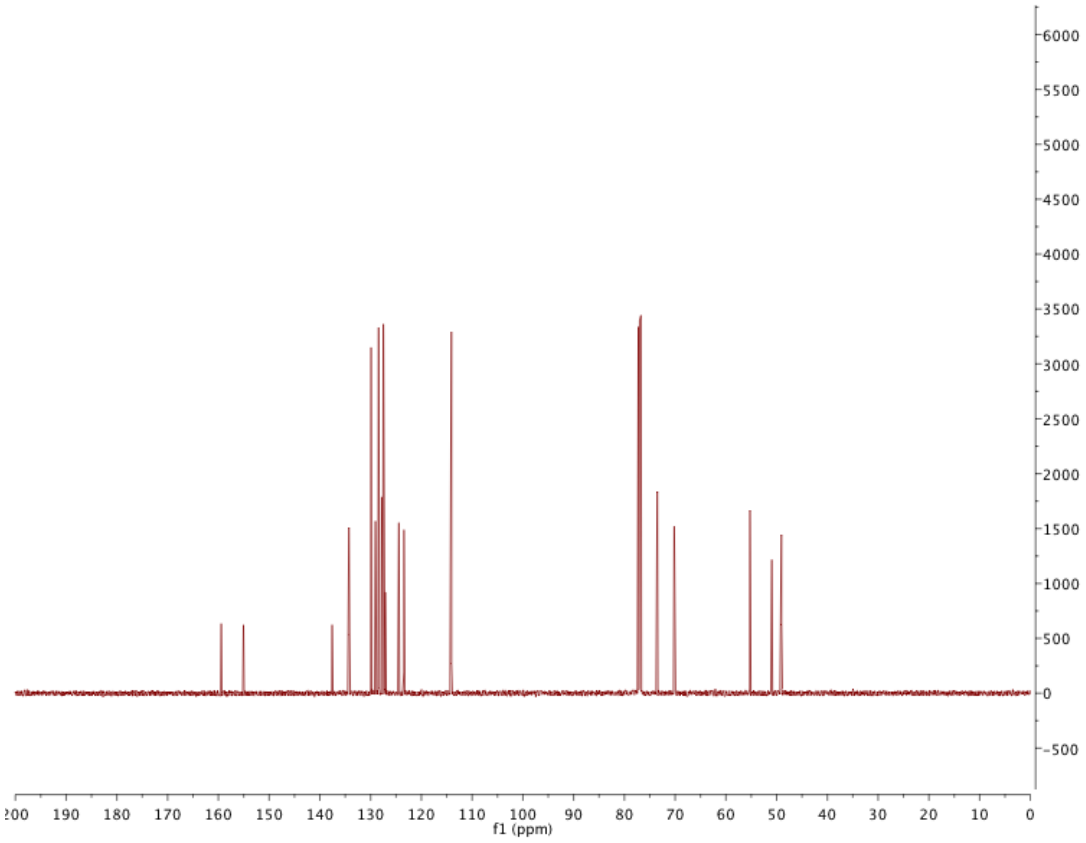
7500
7000
6500
6000
5500
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
-500
-1000
190
170
150
130
110
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)


O
O
S
N
O
O
BnO
90000
85000
80000
75000
70000
65000
60000
55000
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
-5000
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)


6000
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5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
-500
200
190
180
170
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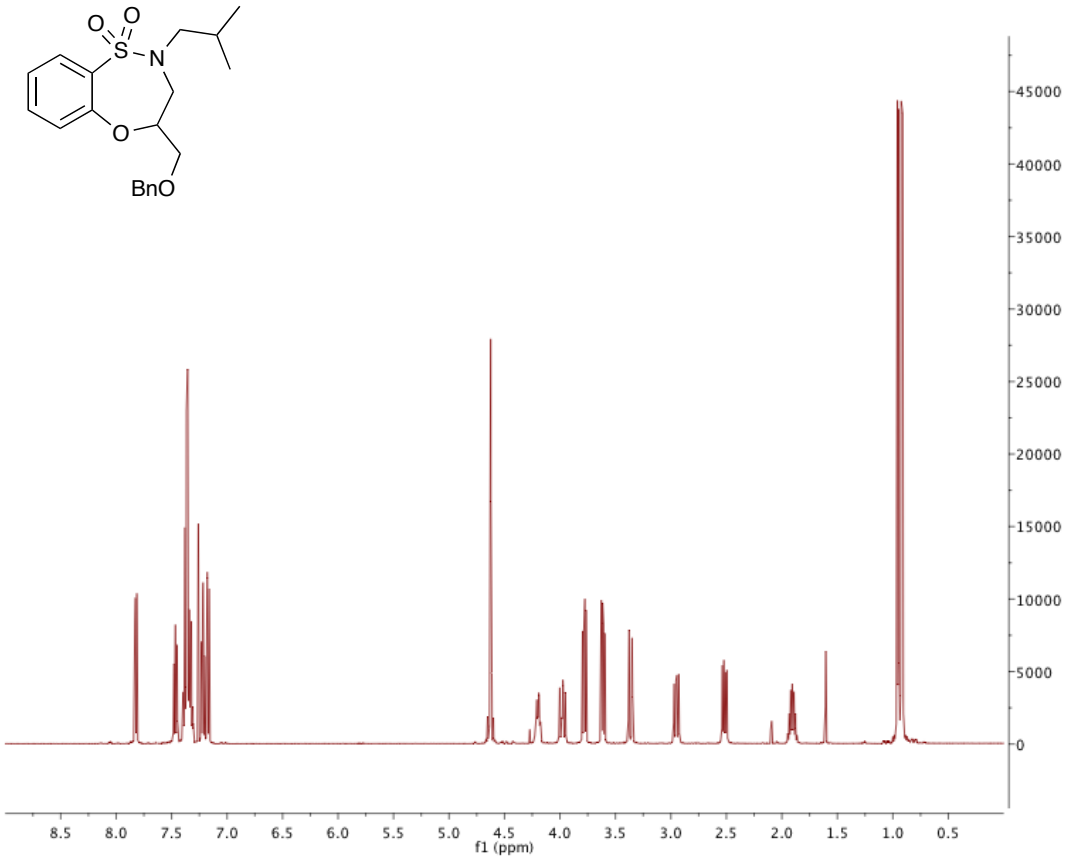
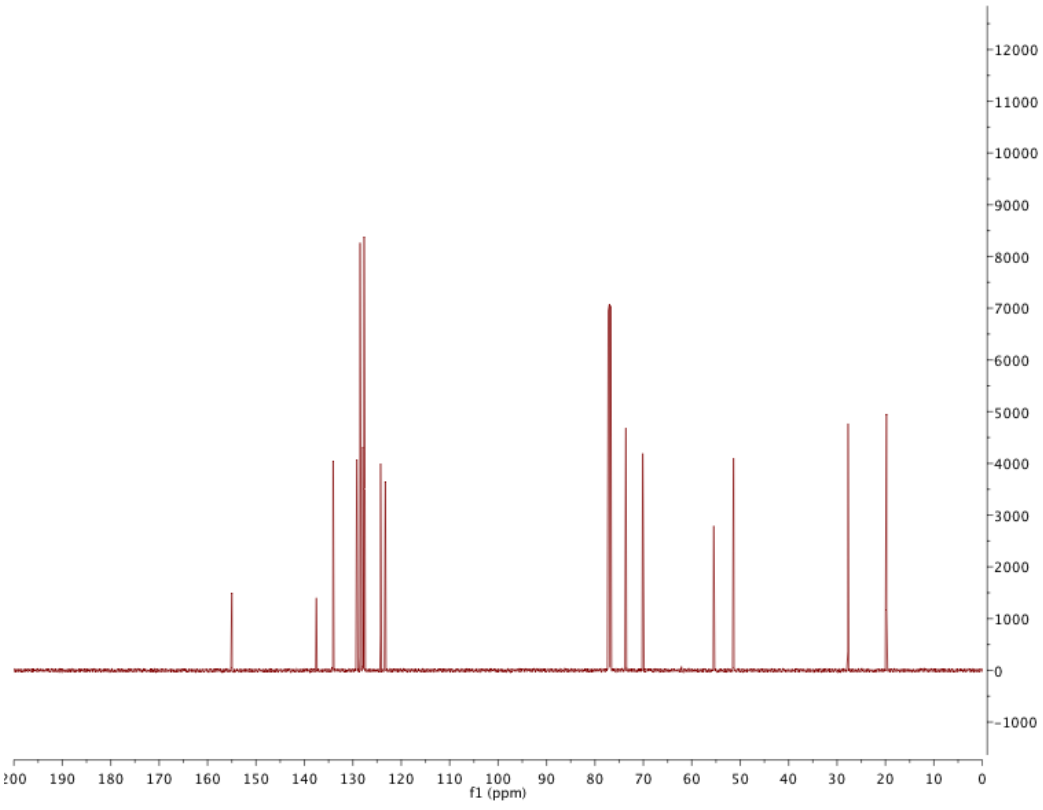
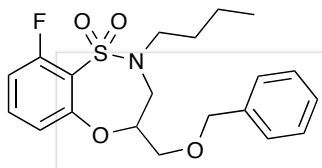
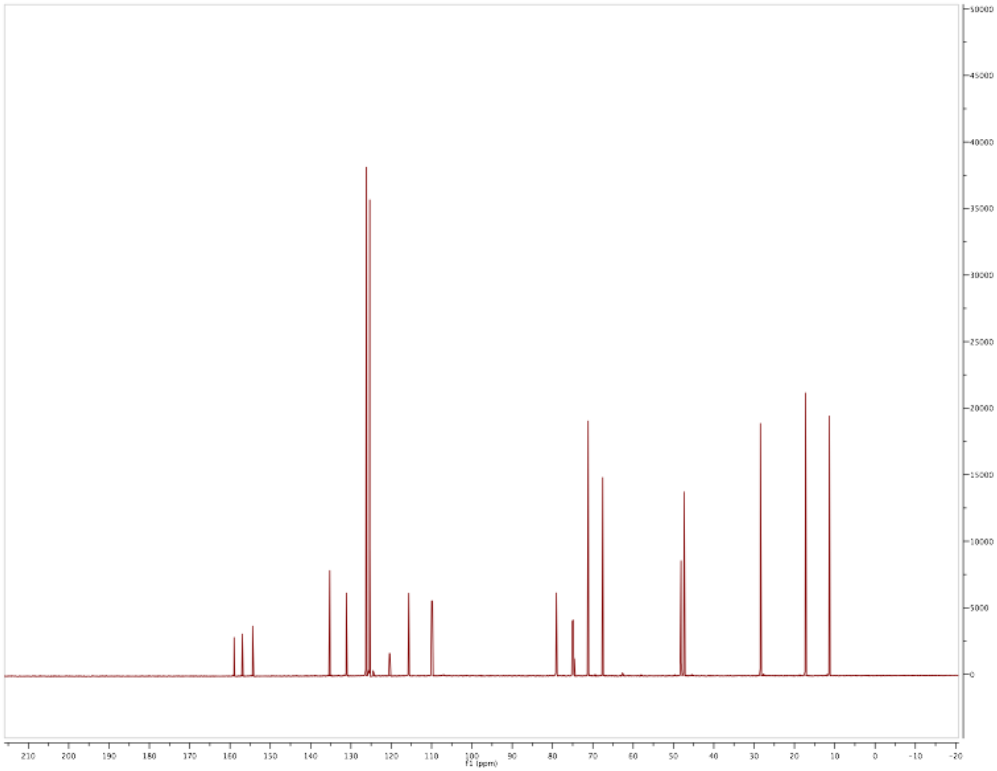
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


O
O
S
N
O
BnO
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
f1 (ppm)


12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
-1000
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


F
O
O
S
N
O
O

1E+05
1E+05
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
-10000
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)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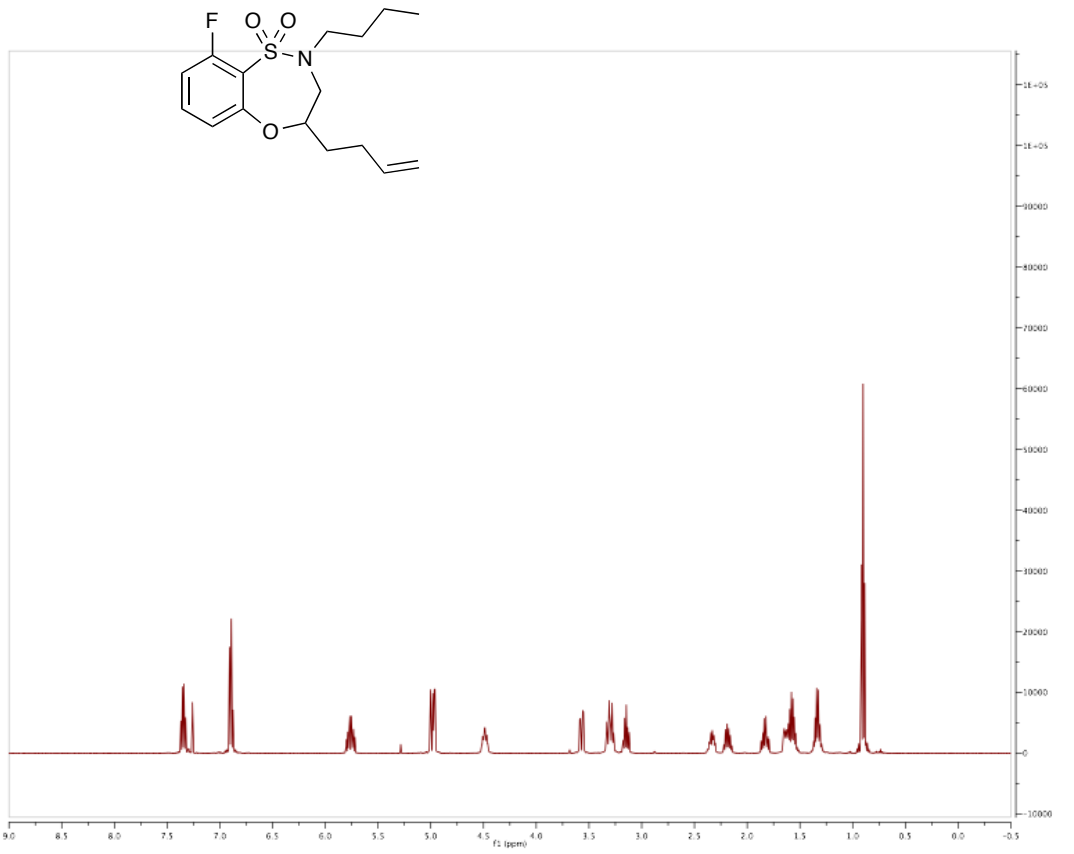
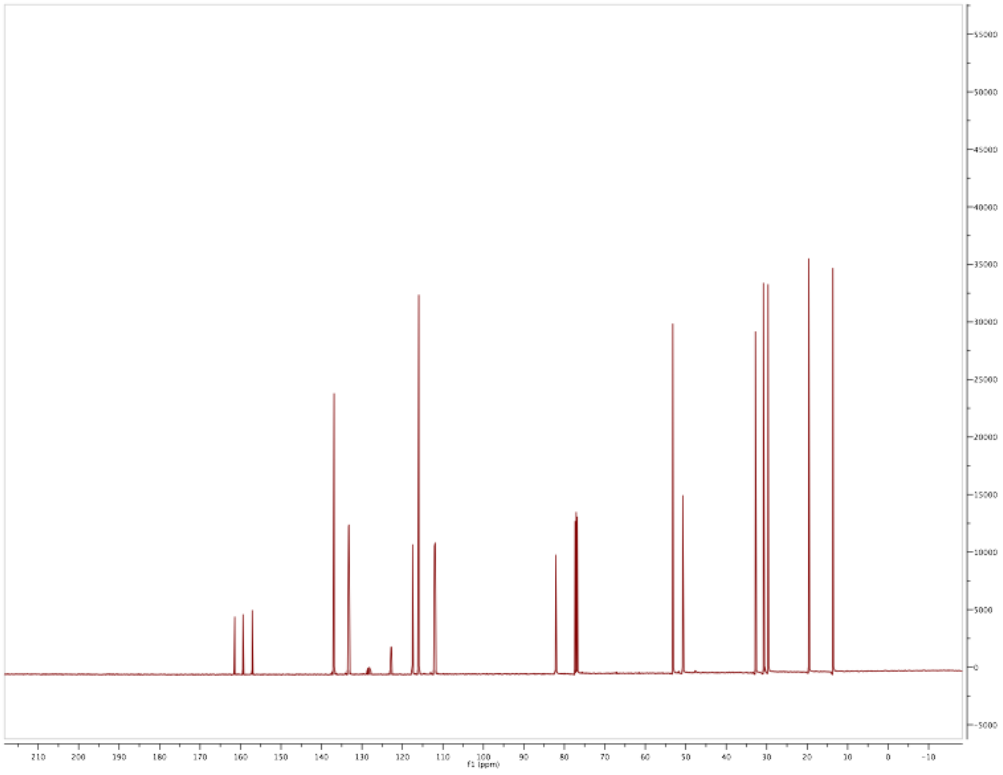
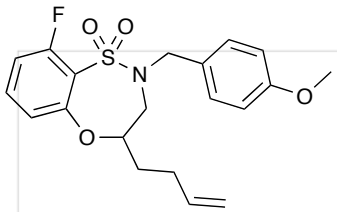
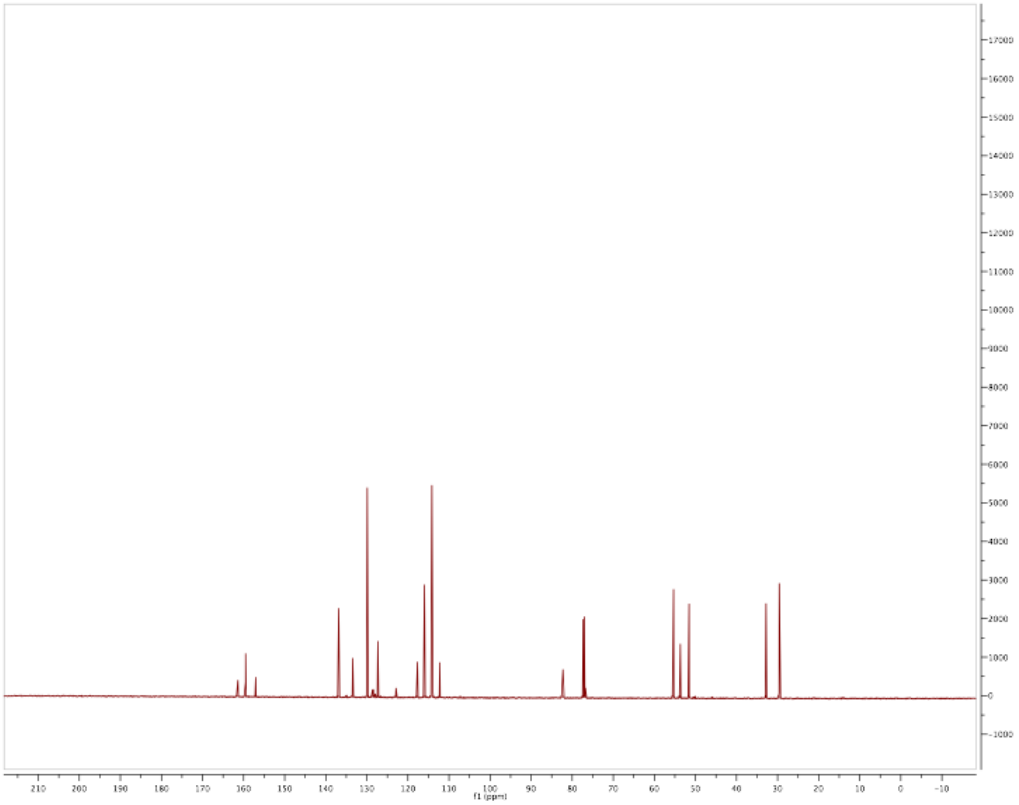
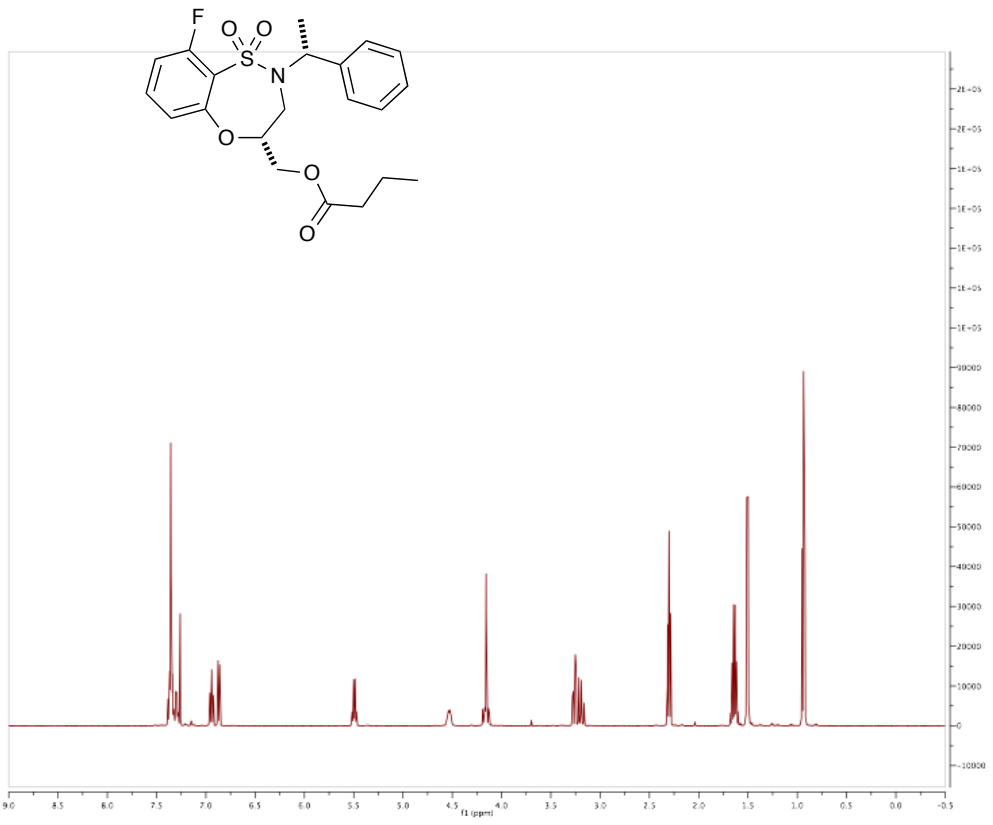
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
-20
f1 (ppm)

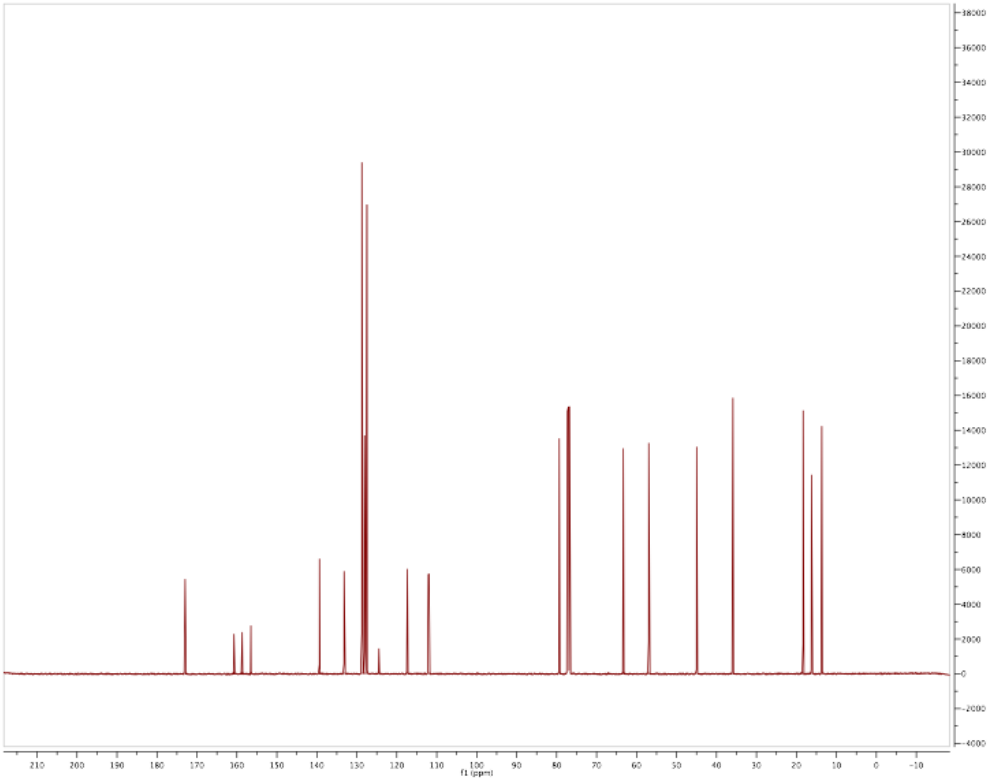

F
O
O
S
N
O
f1 (ppm)

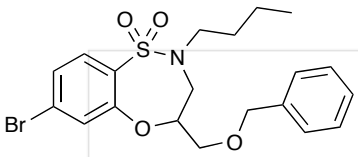

f1 (ppm)

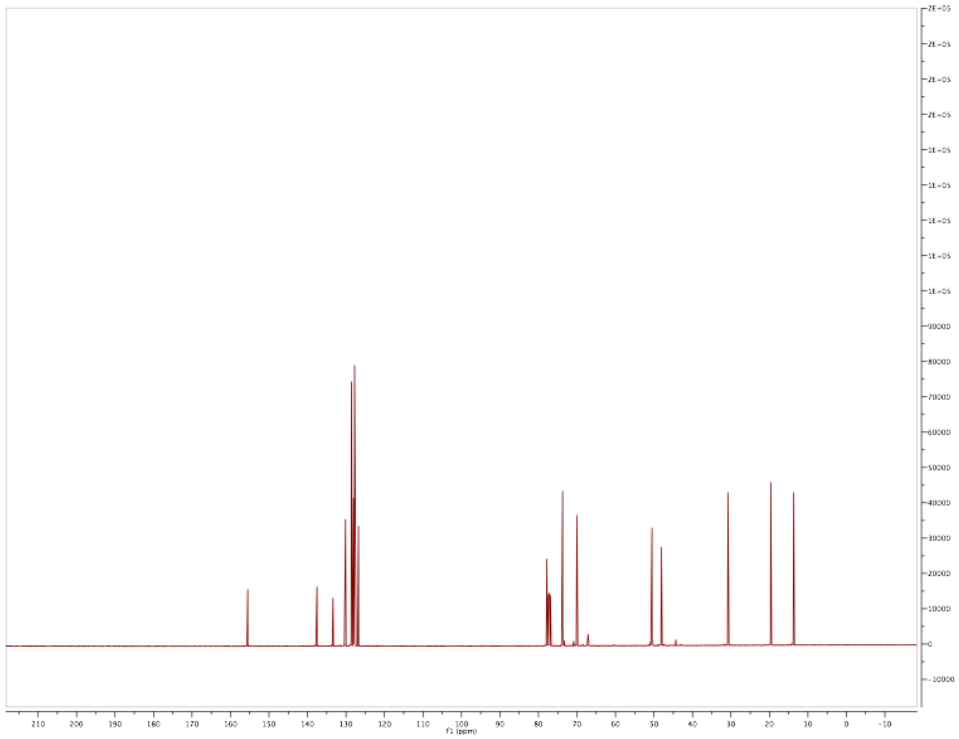

F
O
O
S
N
O
O

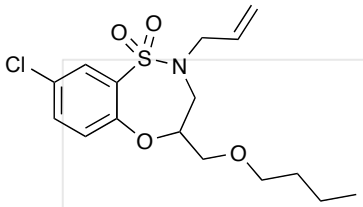


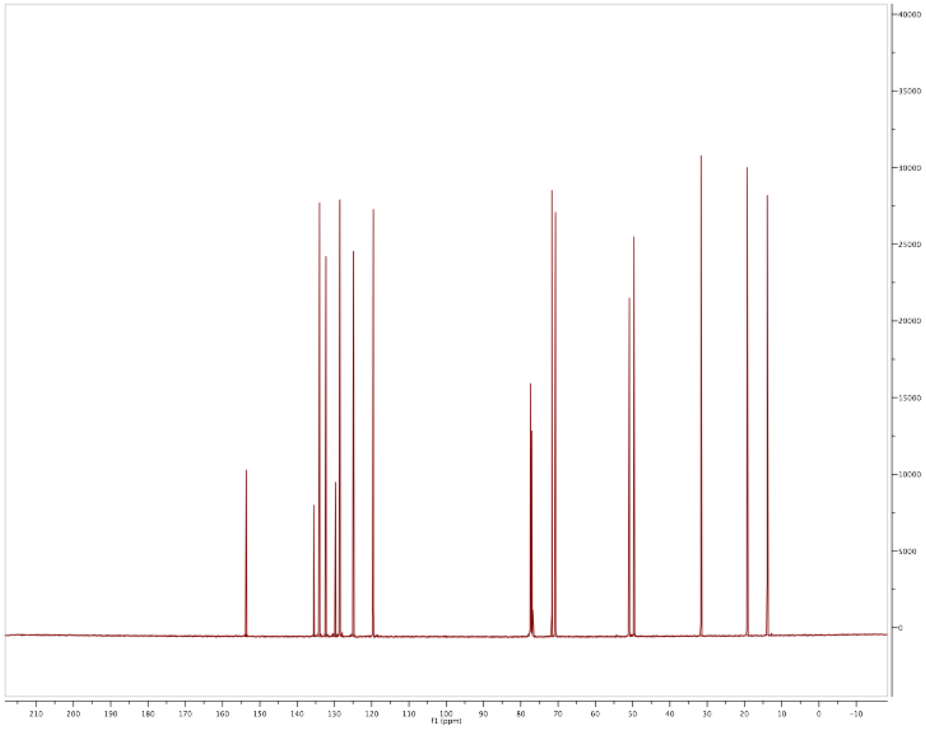

F
O
O
S
N
O
O
O

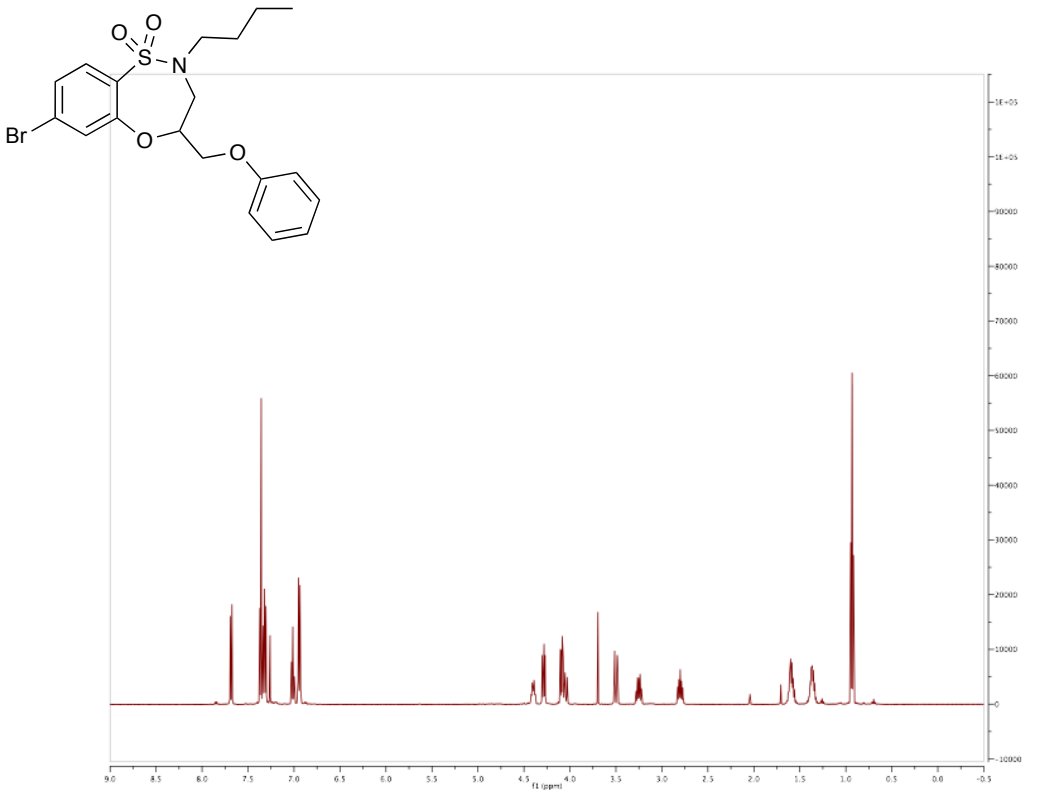


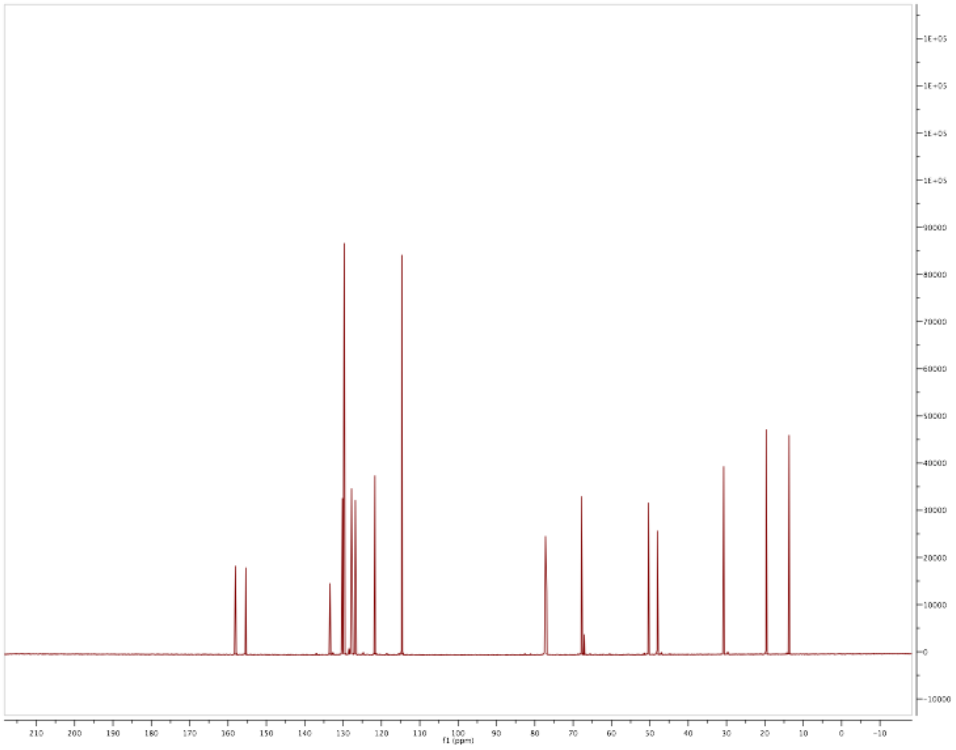

O
O
S
N
Br
O
O

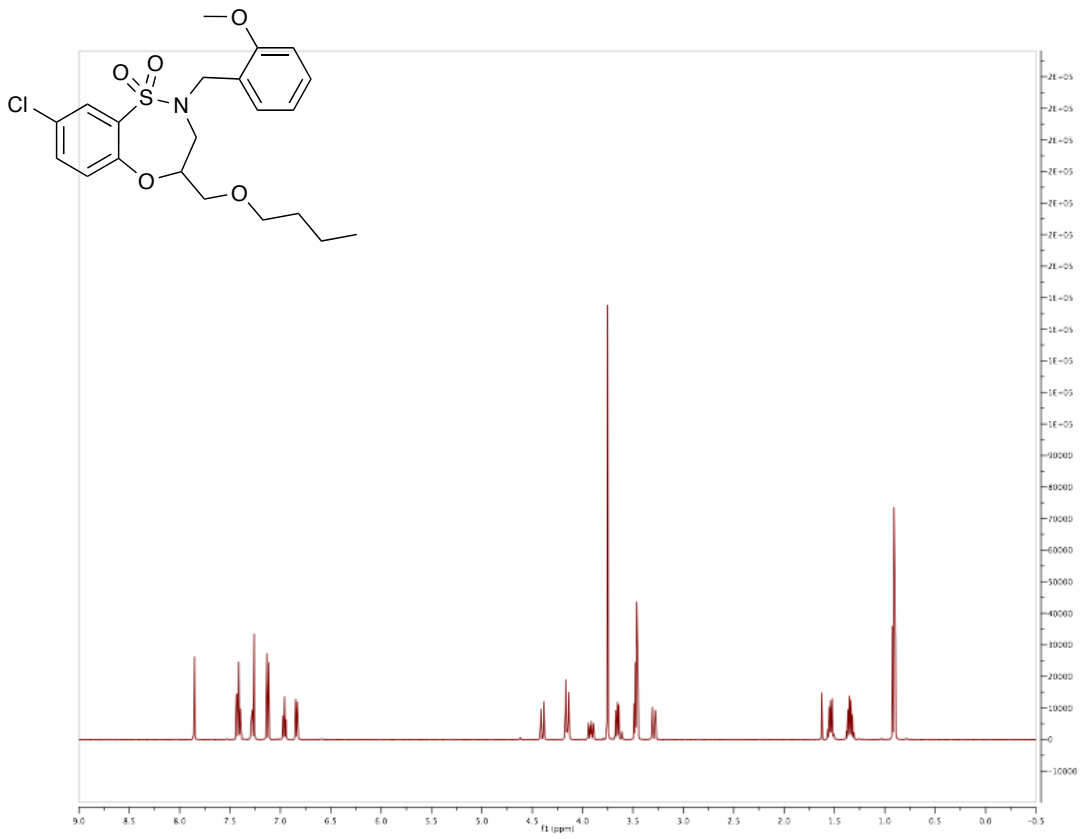


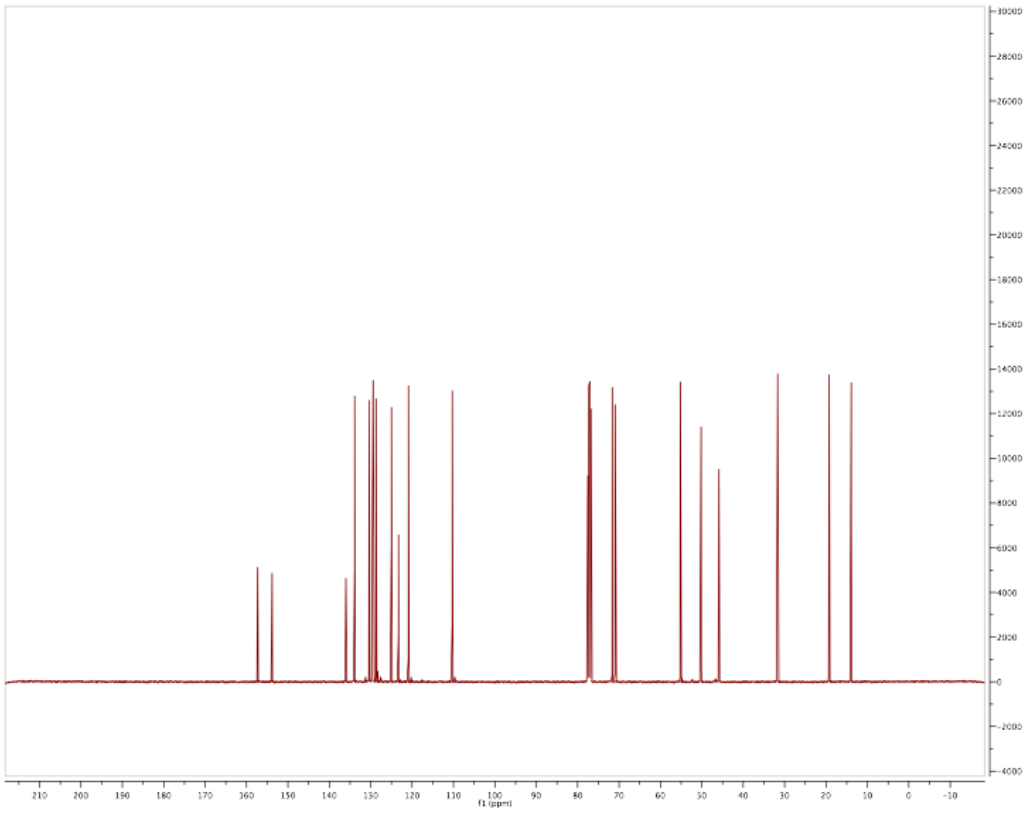

Cl
O
O
S
N
O
O

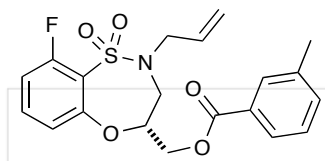


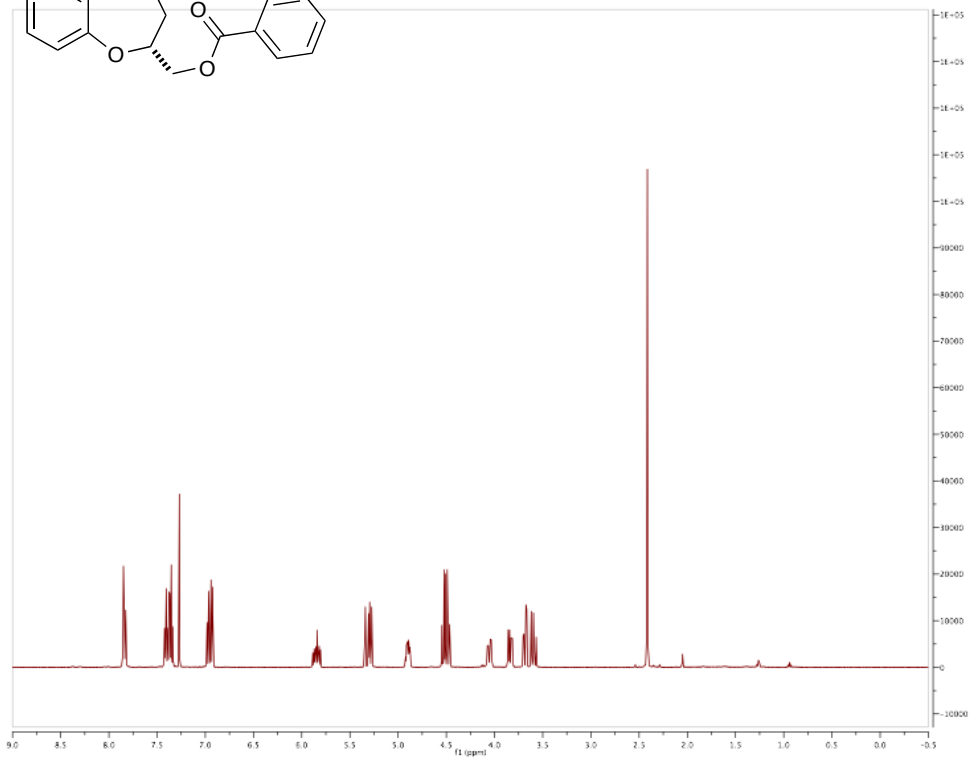

O
O
S
N
Br
O
O
f1 (ppm)

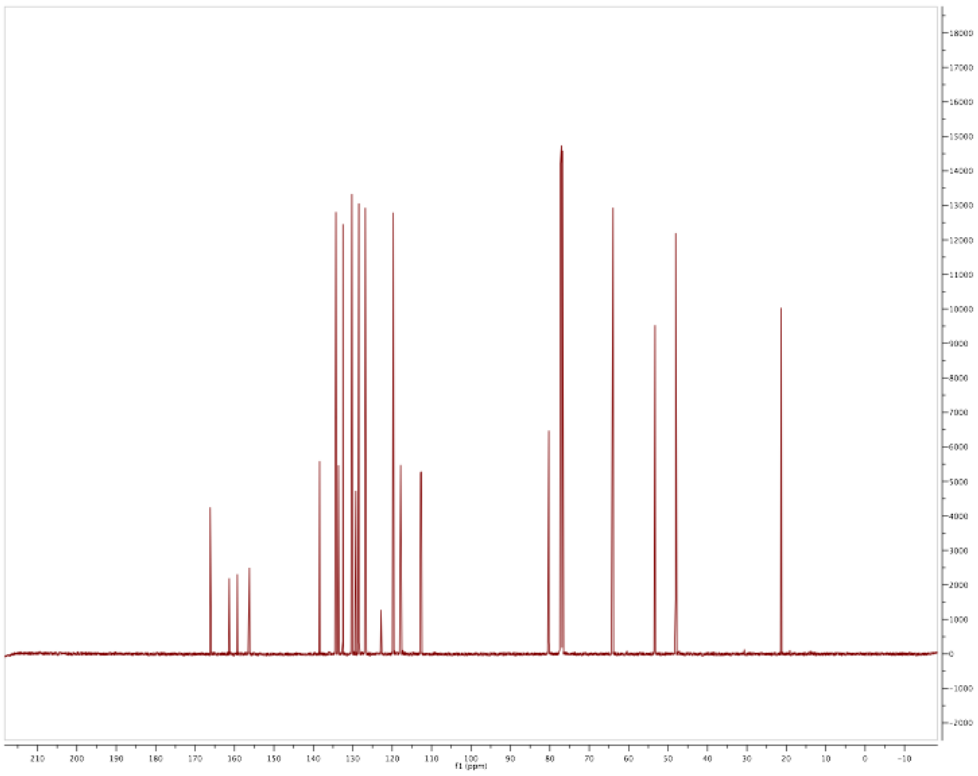

f1 (ppm)

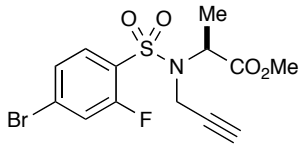

O
O
O
S
N
Cl
O
O
f1 (ppm)


f1 (ppm)

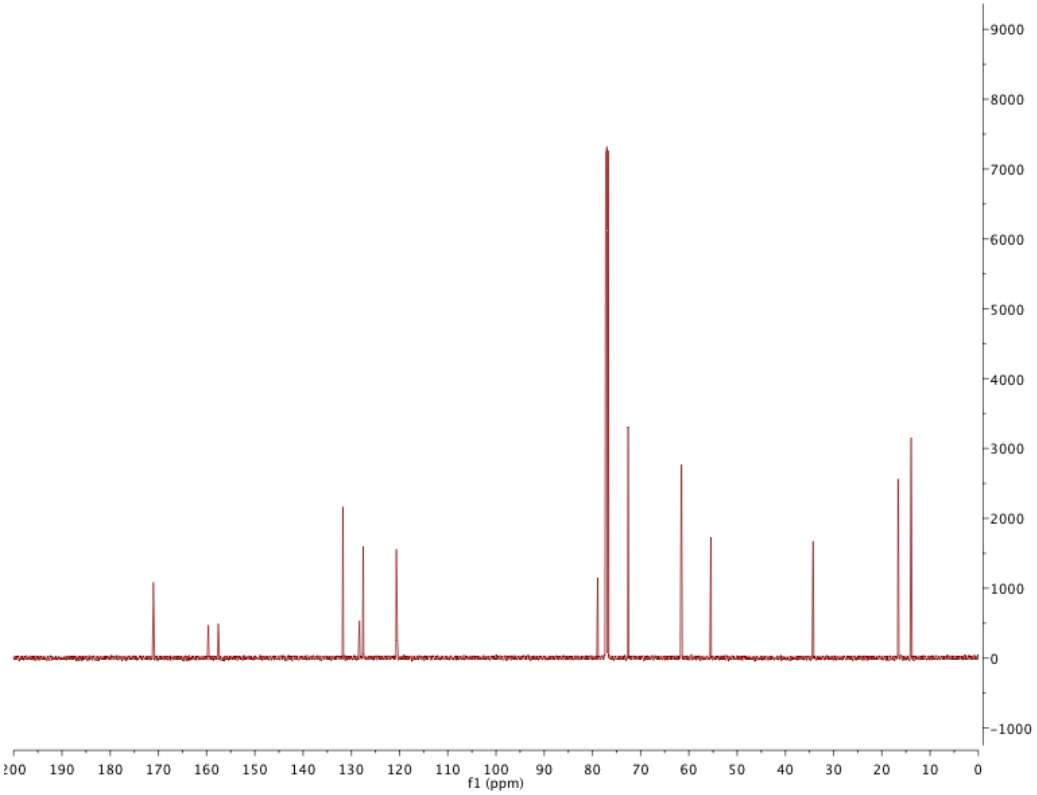

F
O
O
S
N
O
O
O

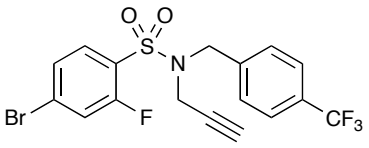

f1 (ppm)


f1 (ppm)

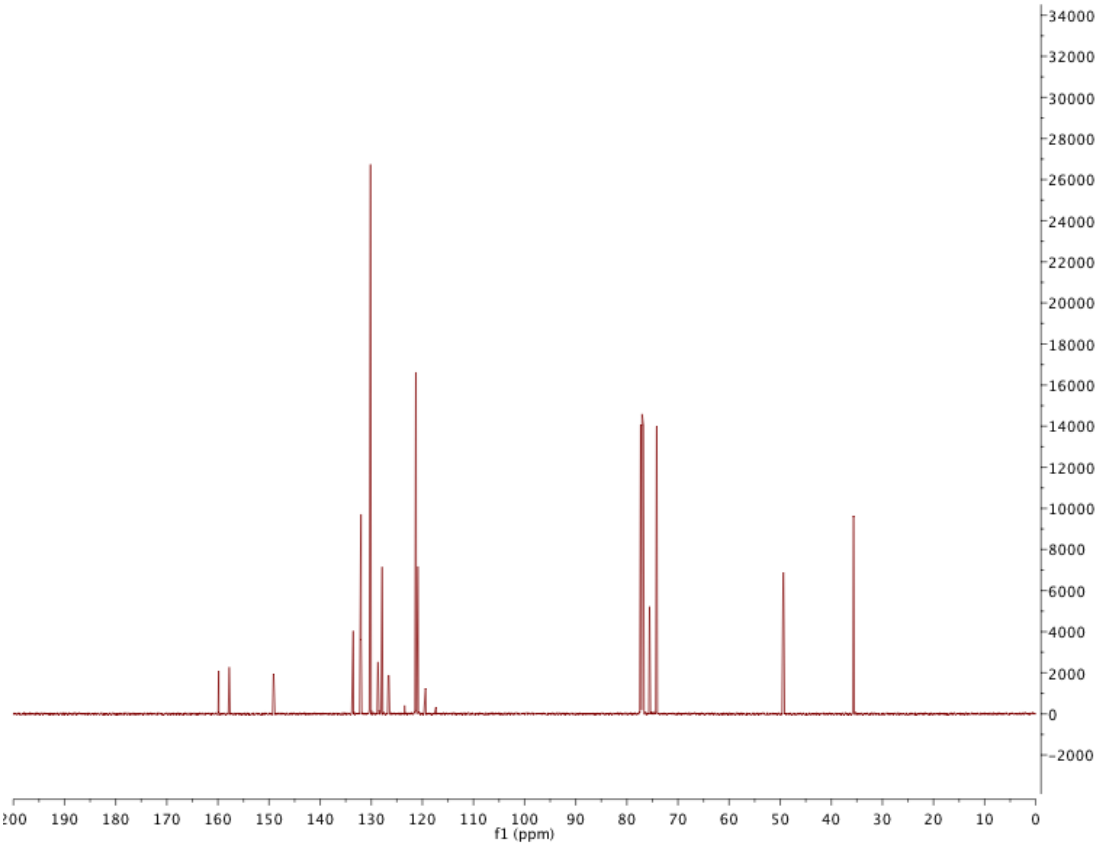

O
O
Me
S
N
CO2Me
Br
F

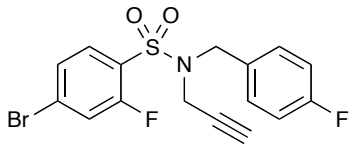
1E+05
1E+05
1E+05
1E+05
1E+05
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
-10000
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)


9000
8000
7000
6000
5000
4000
3000
2000
1000
0
-1000
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

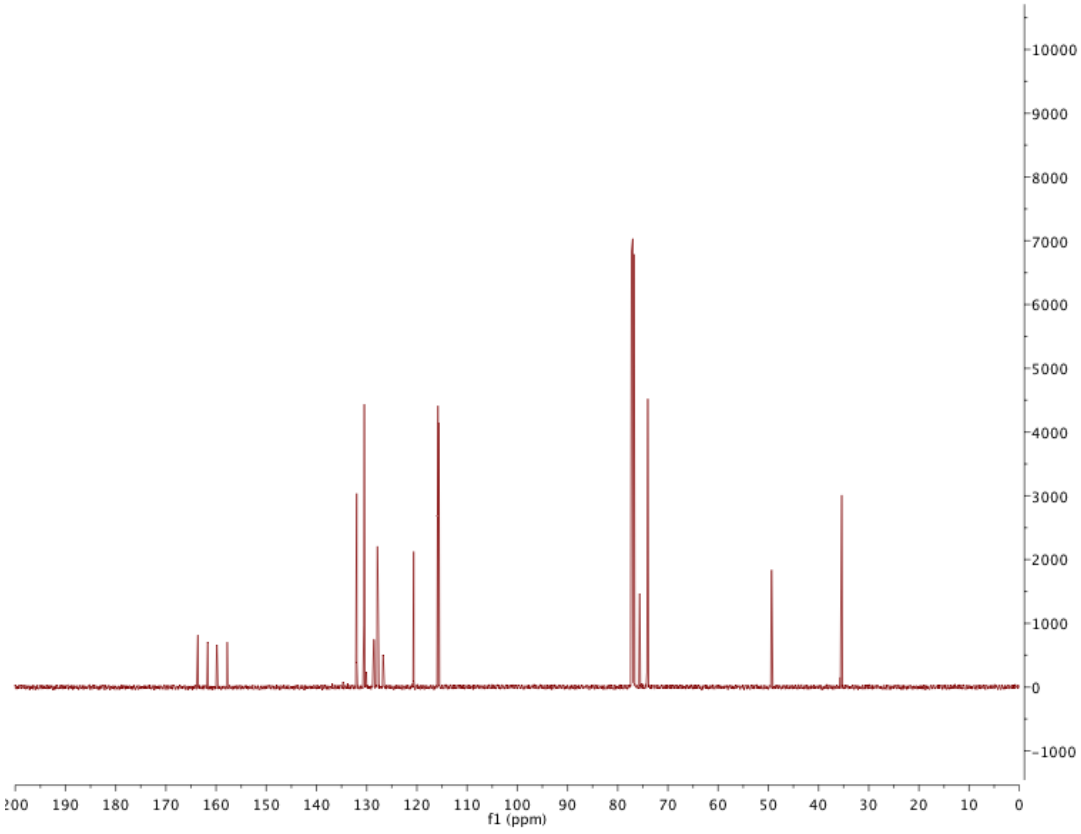

O
O
S
N
Br
F
CF3

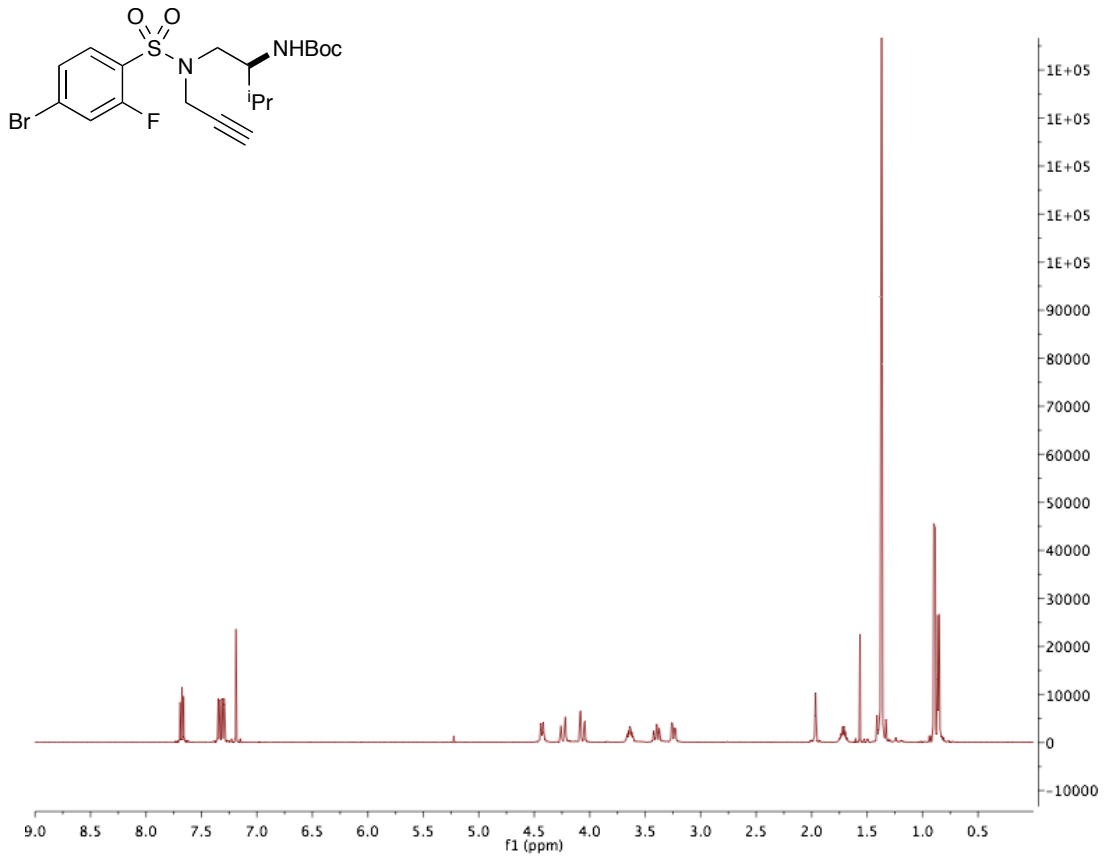
1E+05
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

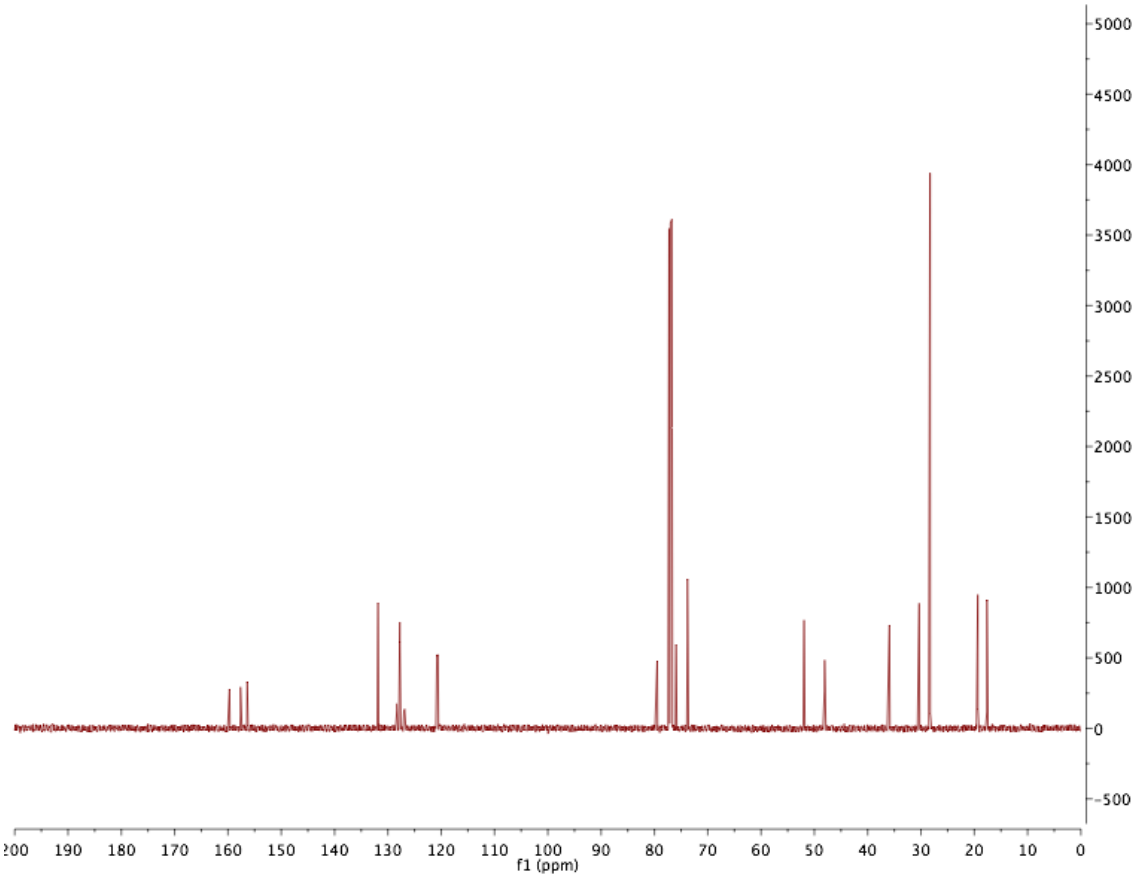

34000
32000
30000
28000
26000
24000
22000
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
-2000
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

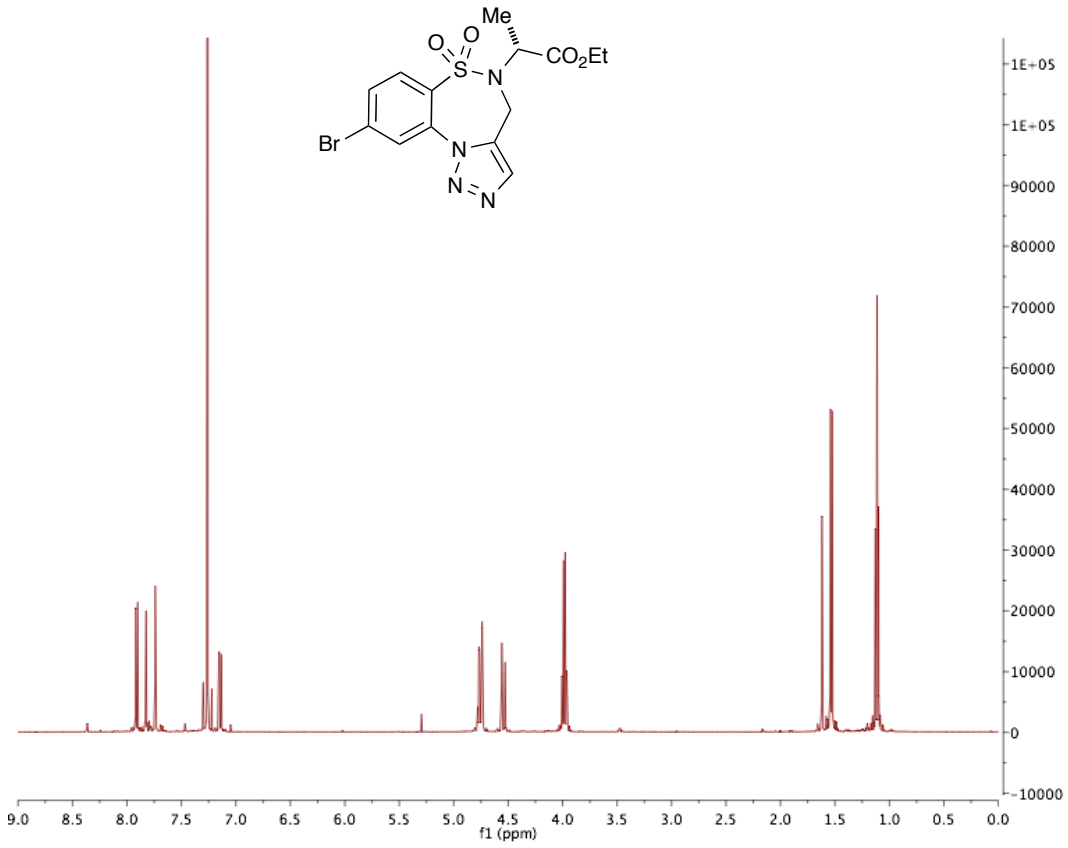

O
O
S
N
Br
F
F

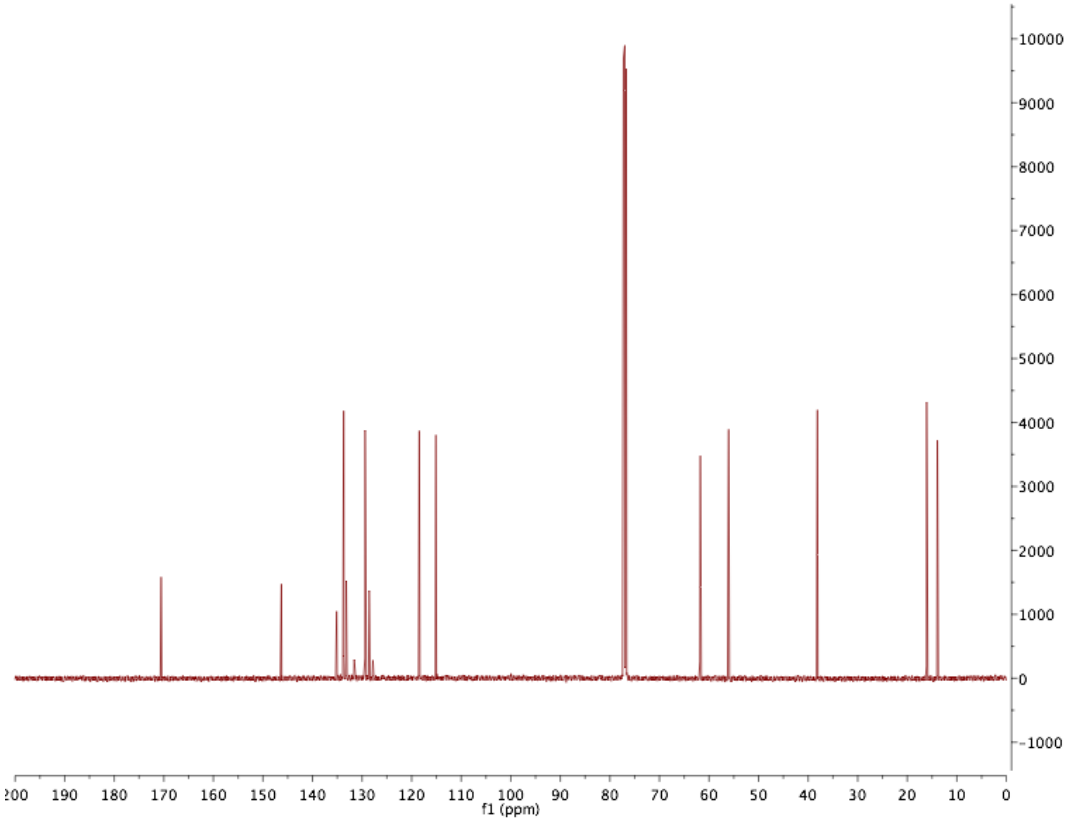
85000
80000
75000
70000
65000
60000
55000
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
-5000
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

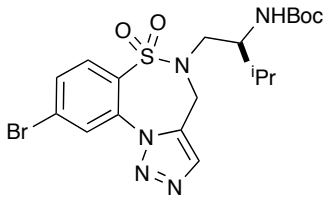

10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
-1000
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


O
O
S
N
NHBoc
iPr
Br
F
1E+05
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
-10000
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)

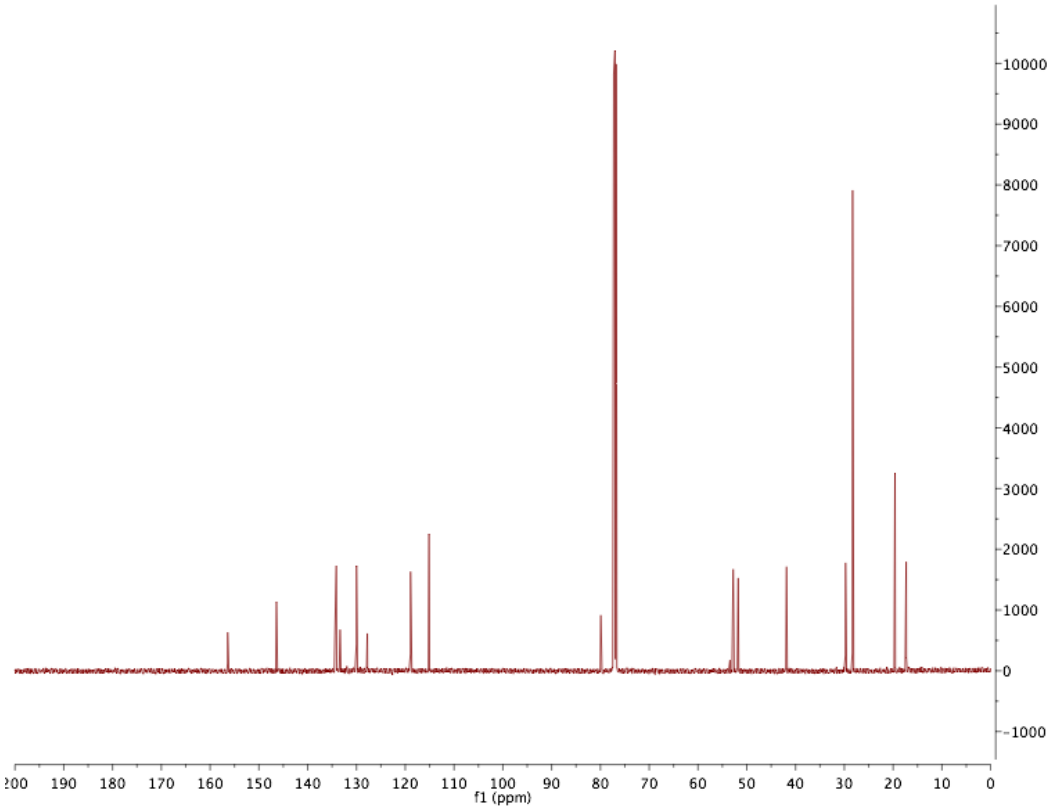

5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
-500
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

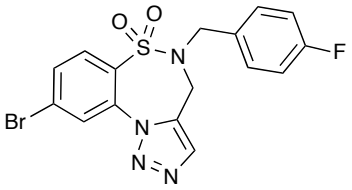

Me
O
O
S
N
CO2Et
Br
N
N
N
1E+05
1E+05
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
-10000
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)


10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
-1000
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

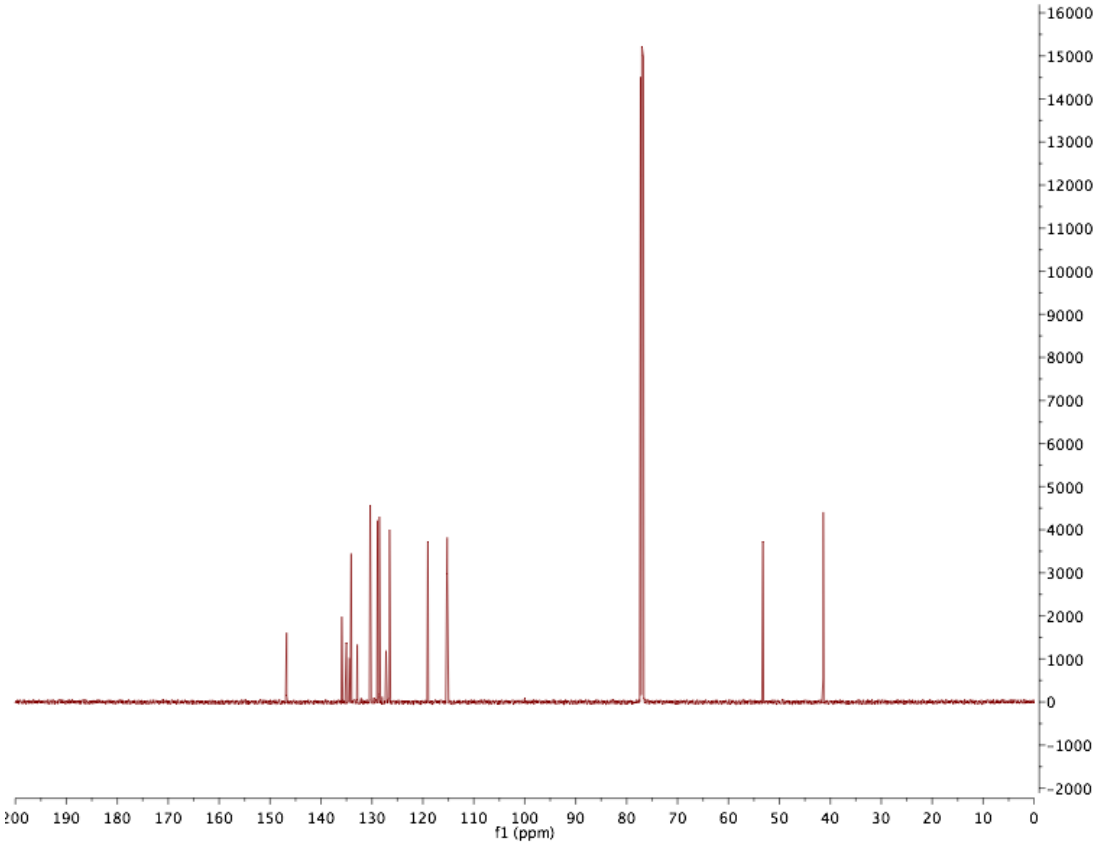

NHBoc
O
O
S
N
iPr
Br
N
N
N

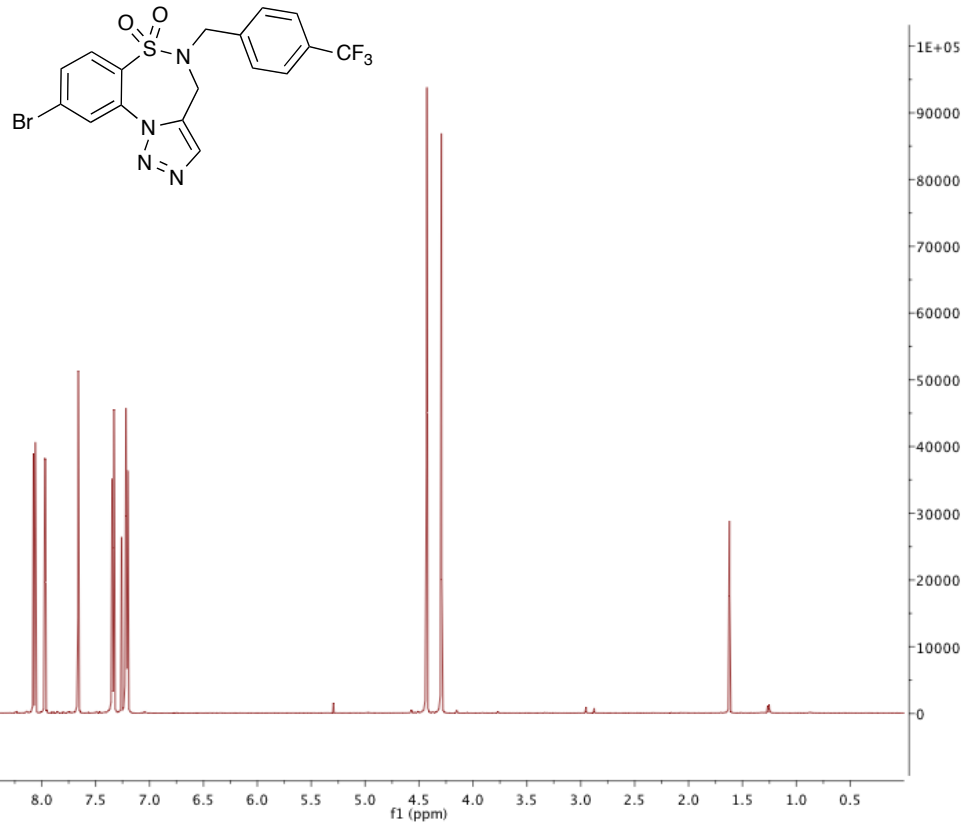
1E+05
1E+05
1E+05
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
-10000
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)

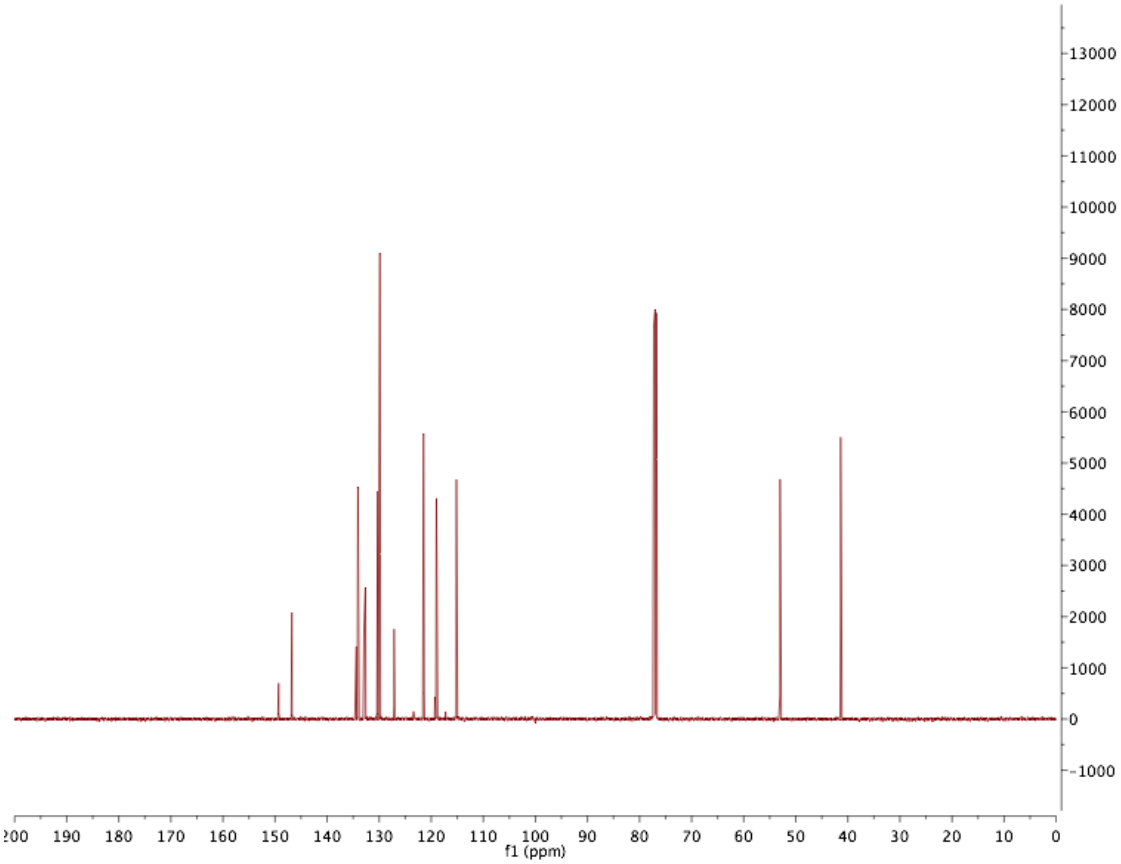

10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
-1000
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

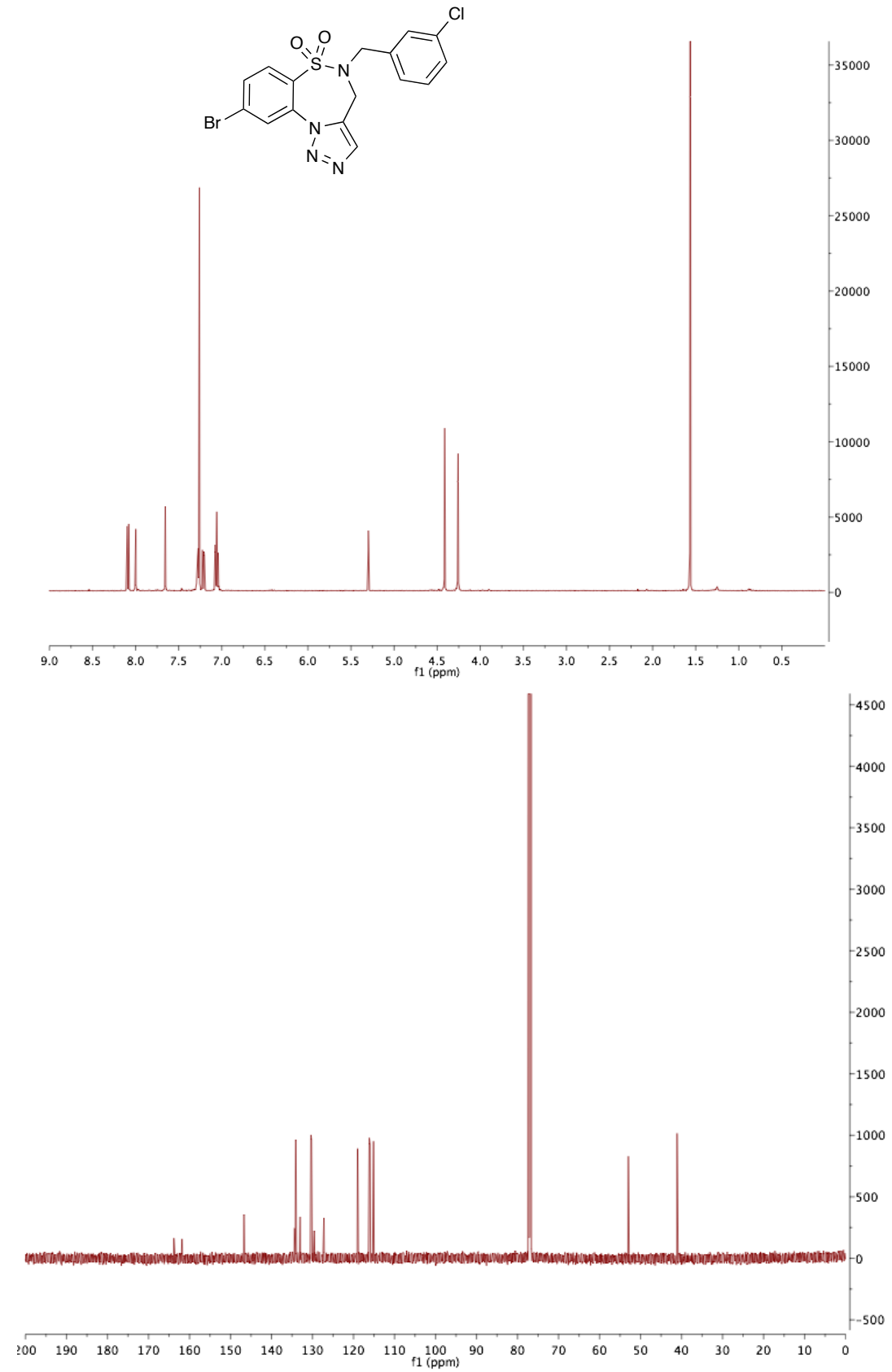

O
O
S
N
F
Br
N
N
N

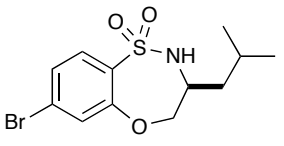
80000
75000
70000
65000
60000
55000
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
-5000
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)


16000
15000
14000
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
-1000
-2000
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

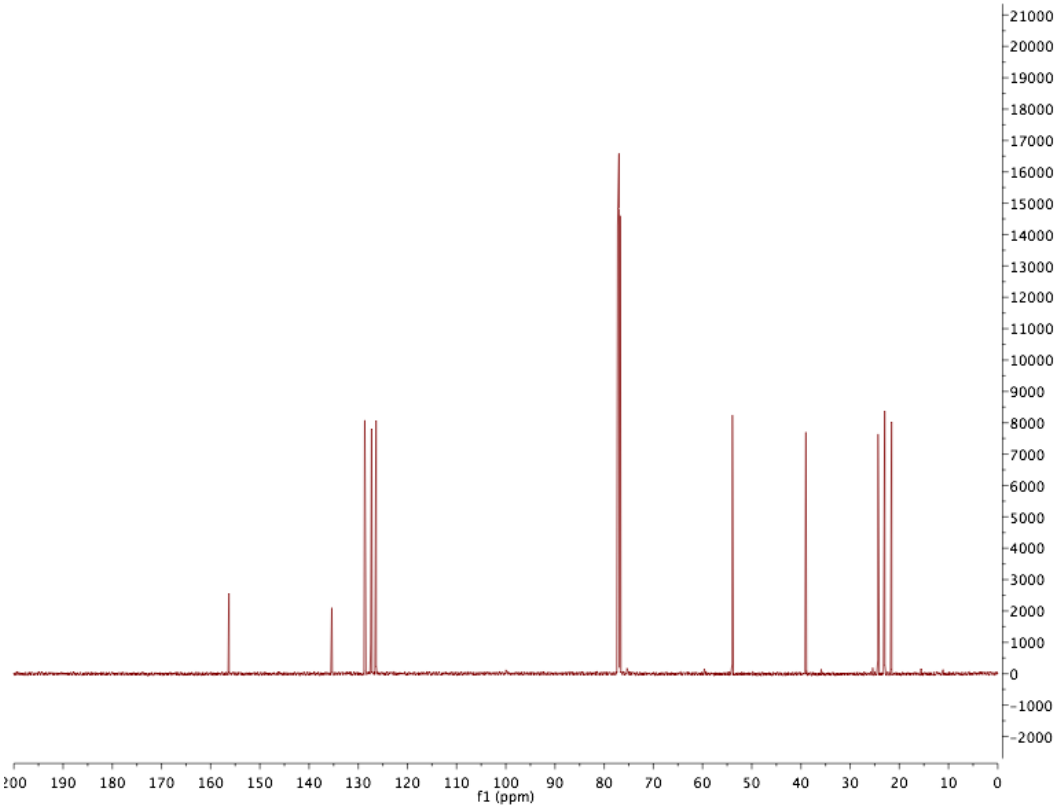

O
O
S
N
CF3
Br
N
N
N
1E+05
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)

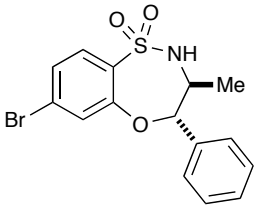

13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
-1000
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


Cl
O
O
S
N
Br
N
N
N
35000
30000
25000
20000
15000
10000
5000
0
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
f1 (ppm)
4500
4000
3500
3000
2500
2000
1500
1000
500
0
-500
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

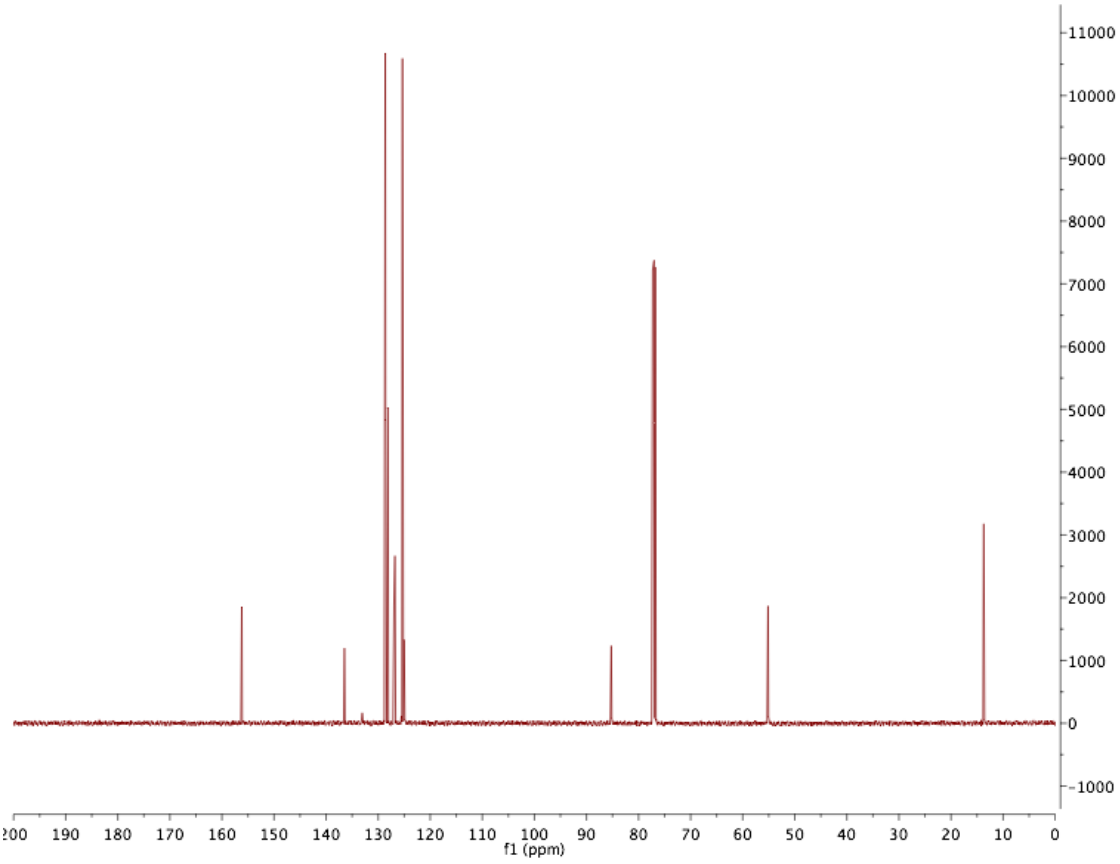

O
O
S
NH
Br
O

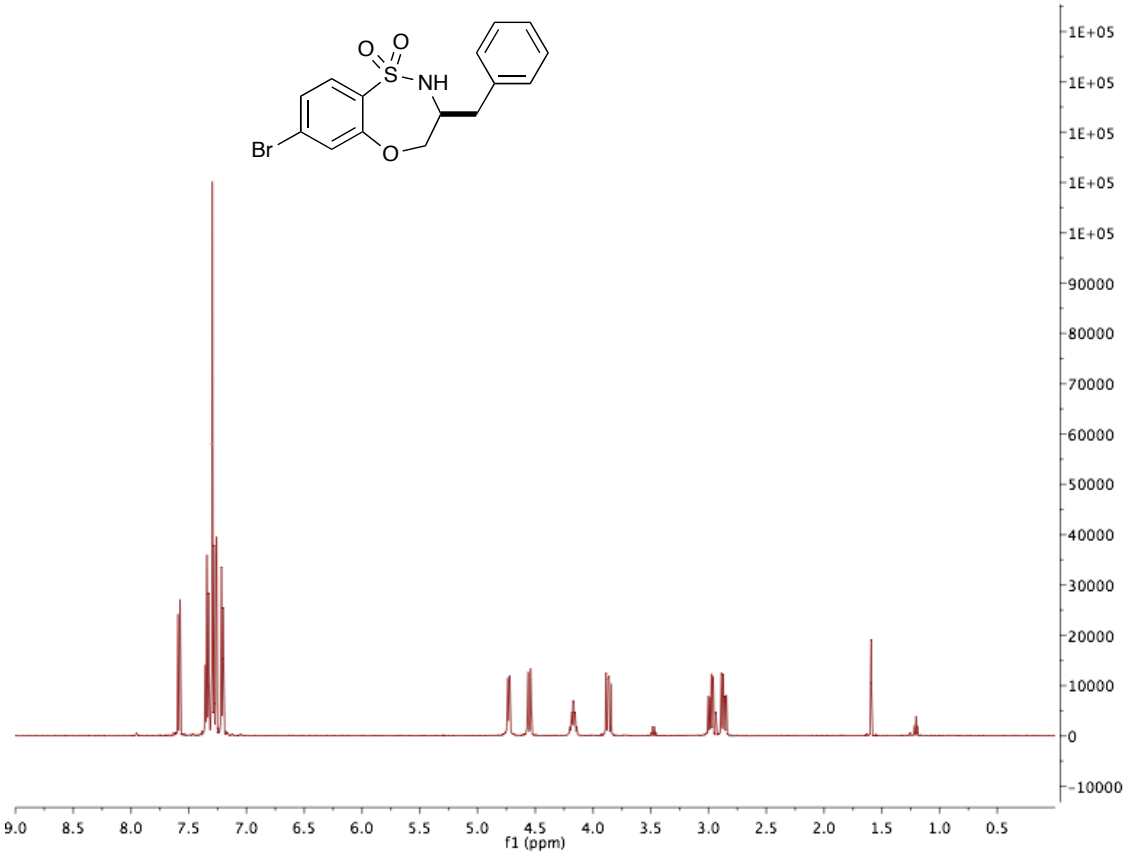
75000
70000
65000
60000
55000
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
-5000
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

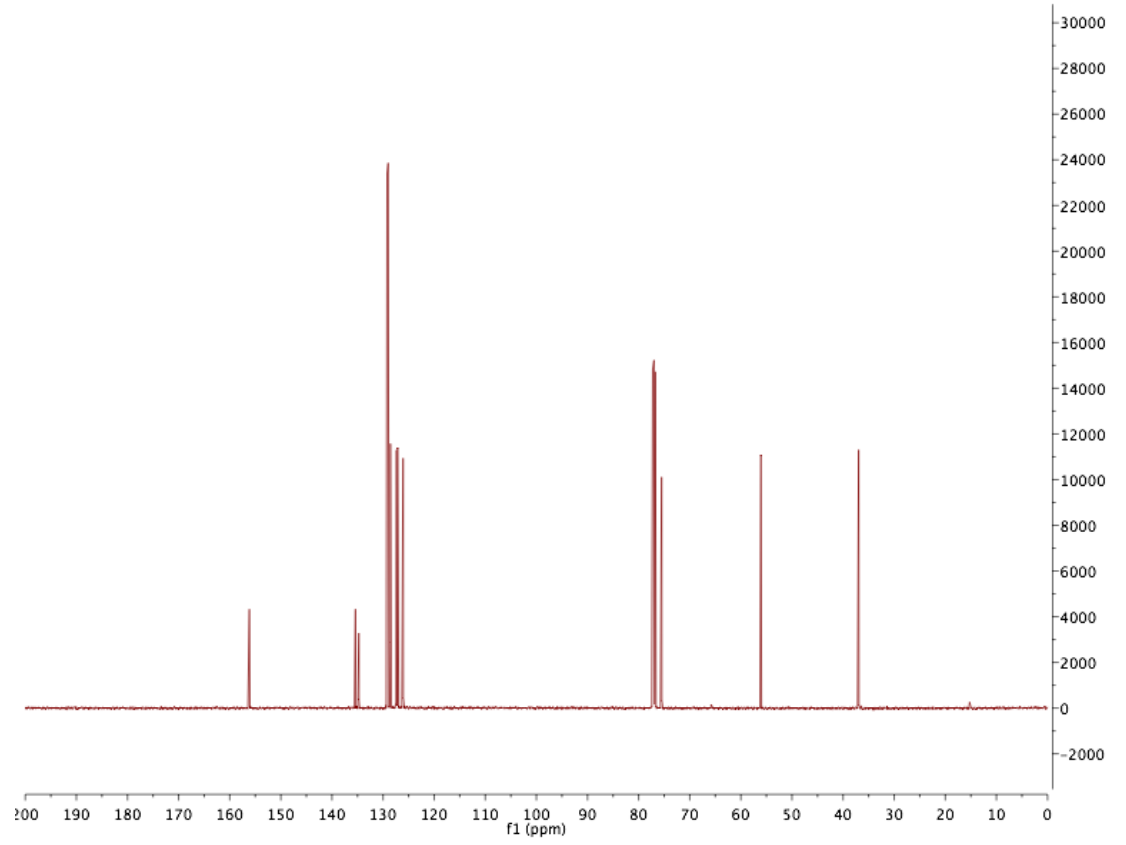

21000
20000
19000
18000
17000
16000
15000
14000
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
-1000
-2000
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

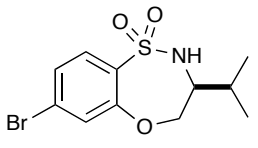

O
O
S
NH
Me
Br
O

90000
85000
80000
75000
70000
65000
60000
55000
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
-5000
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

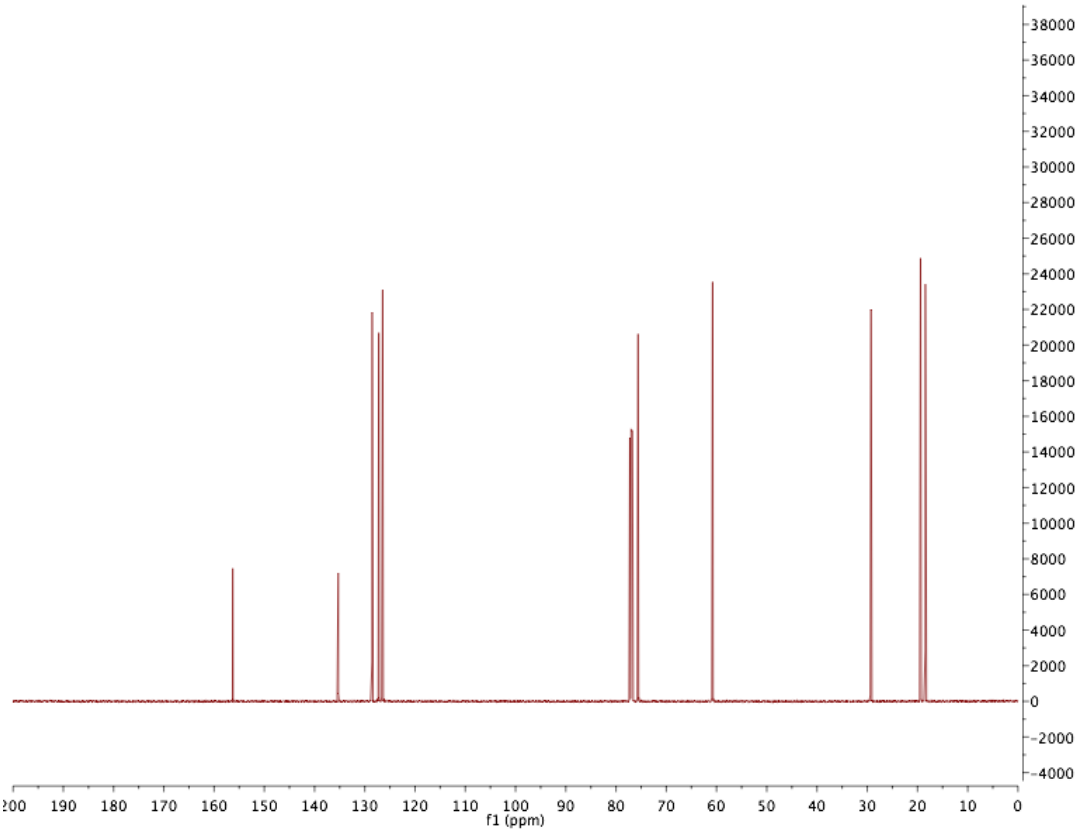

11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
-1000
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

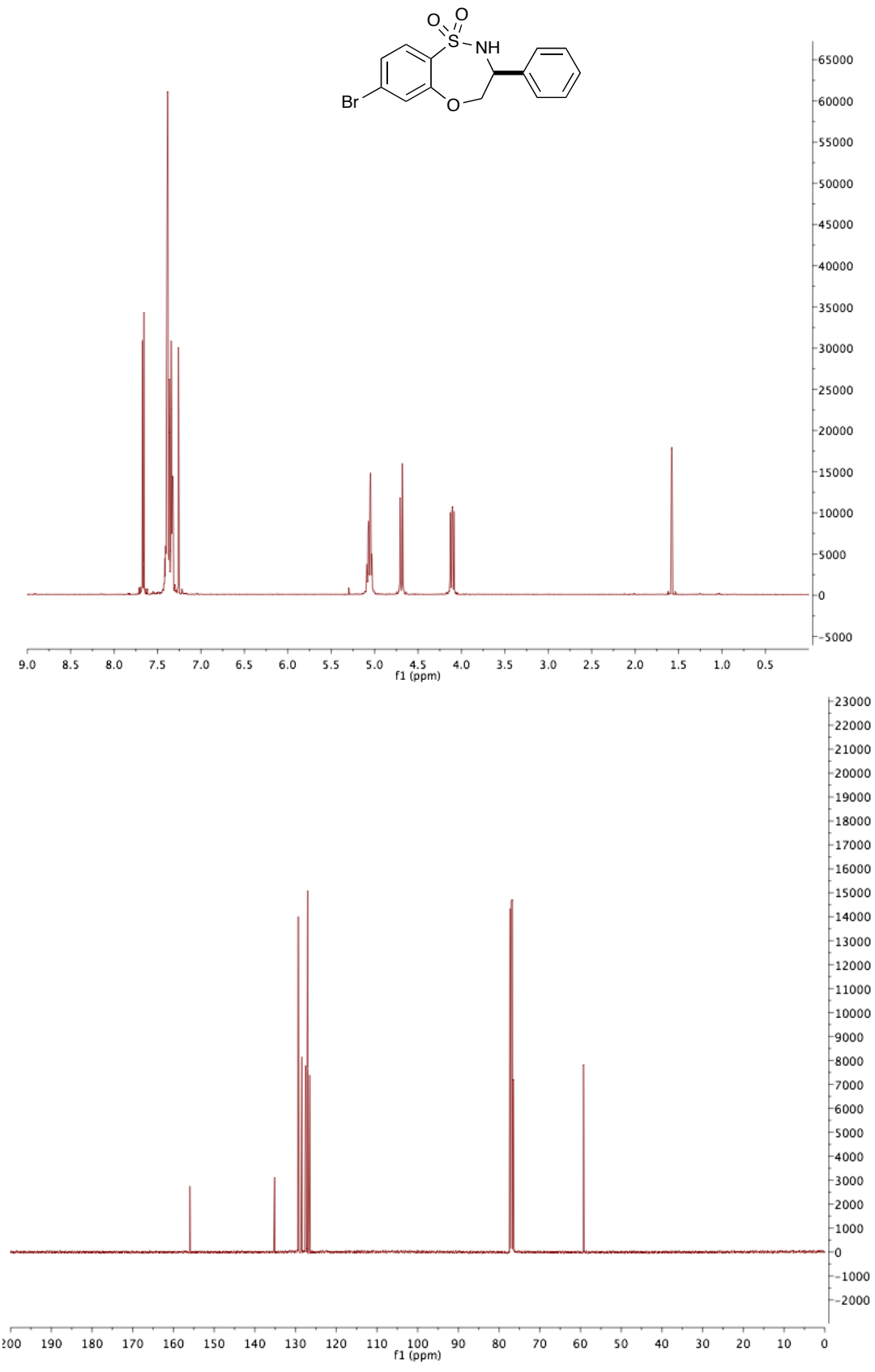

O
O
S
NH
Br
O
1E+05
1E+05
1E+05
1E+05
1E+05
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
-10000
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)

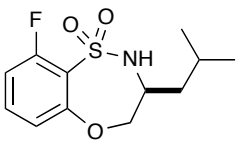

30000
28000
26000
24000
22000
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
-2000
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


O
O
S
NH
Br
O

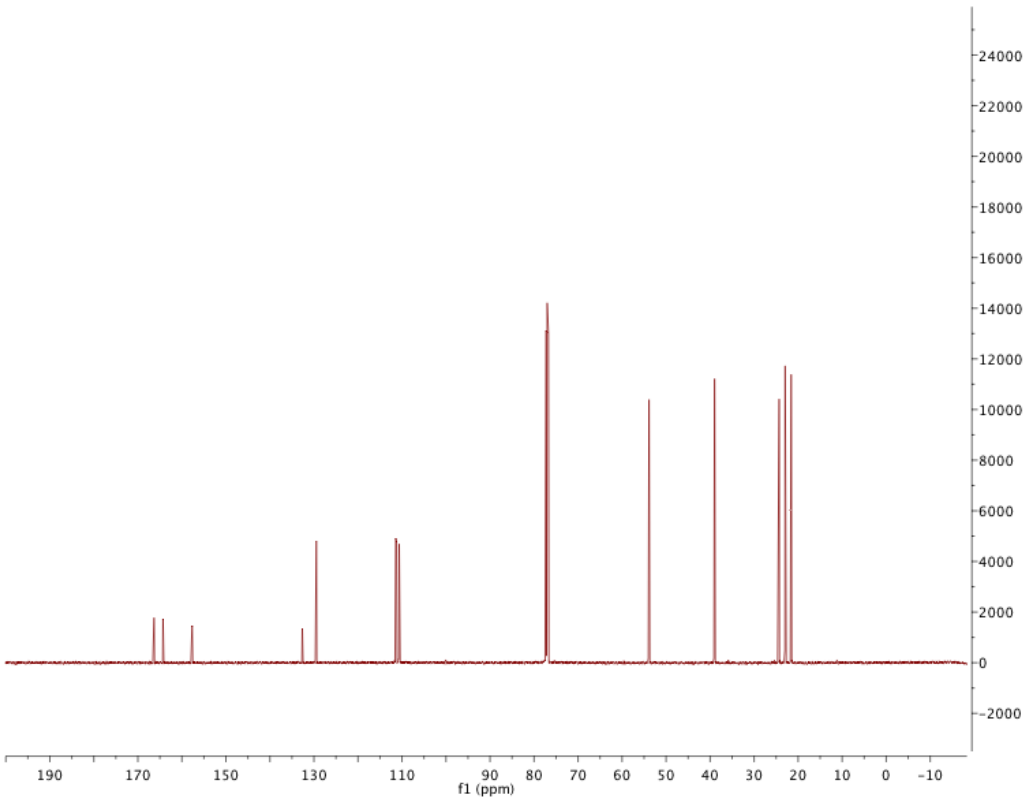
1E+05
1E+05
1E+05
1E+05
1E+05
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
-10000
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
f1 (ppm)

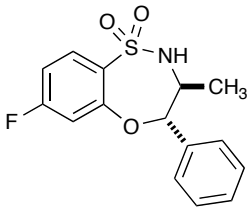

38000
36000
34000
32000
30000
28000
26000
24000
22000
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
-2000
-4000
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


O
O
S
NH
Br
O
f1 (ppm)
f1 (ppm)

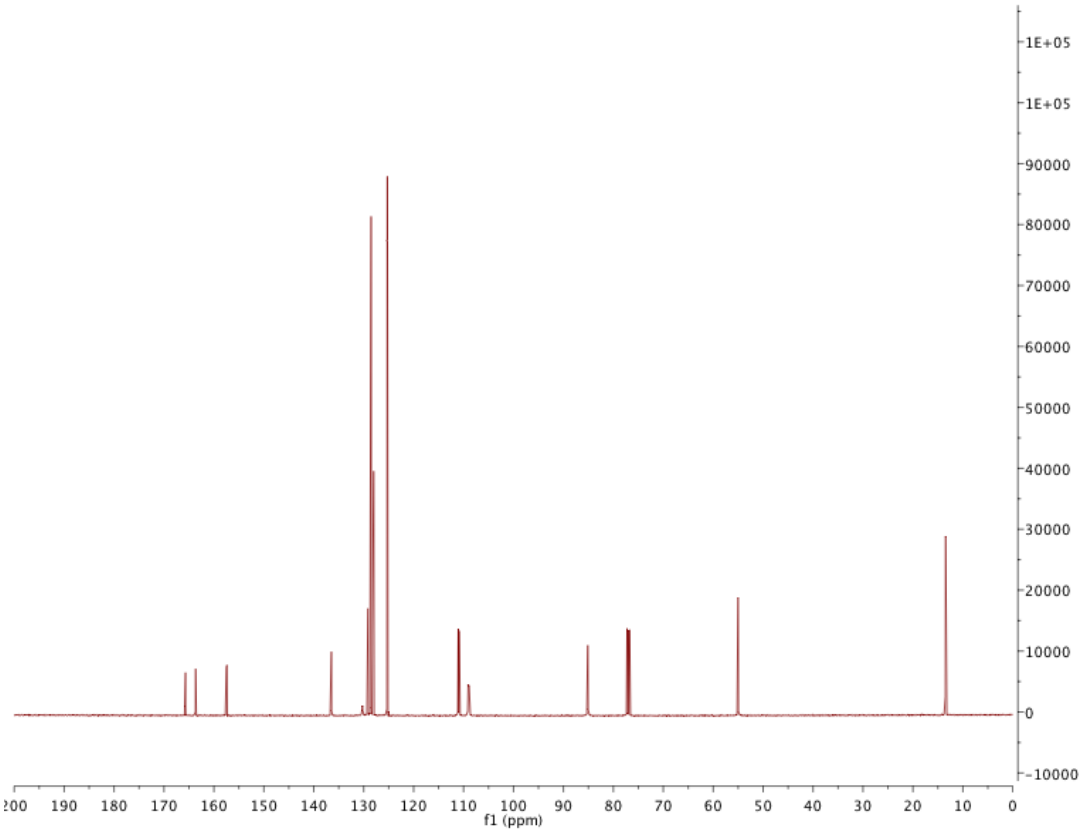

F
O
O
S
NH
O

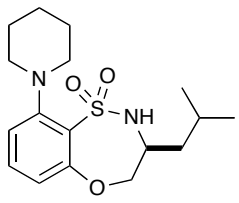
1E+05
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
f1 (ppm)


24000
22000
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
-2000
190 170 150 130 110 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

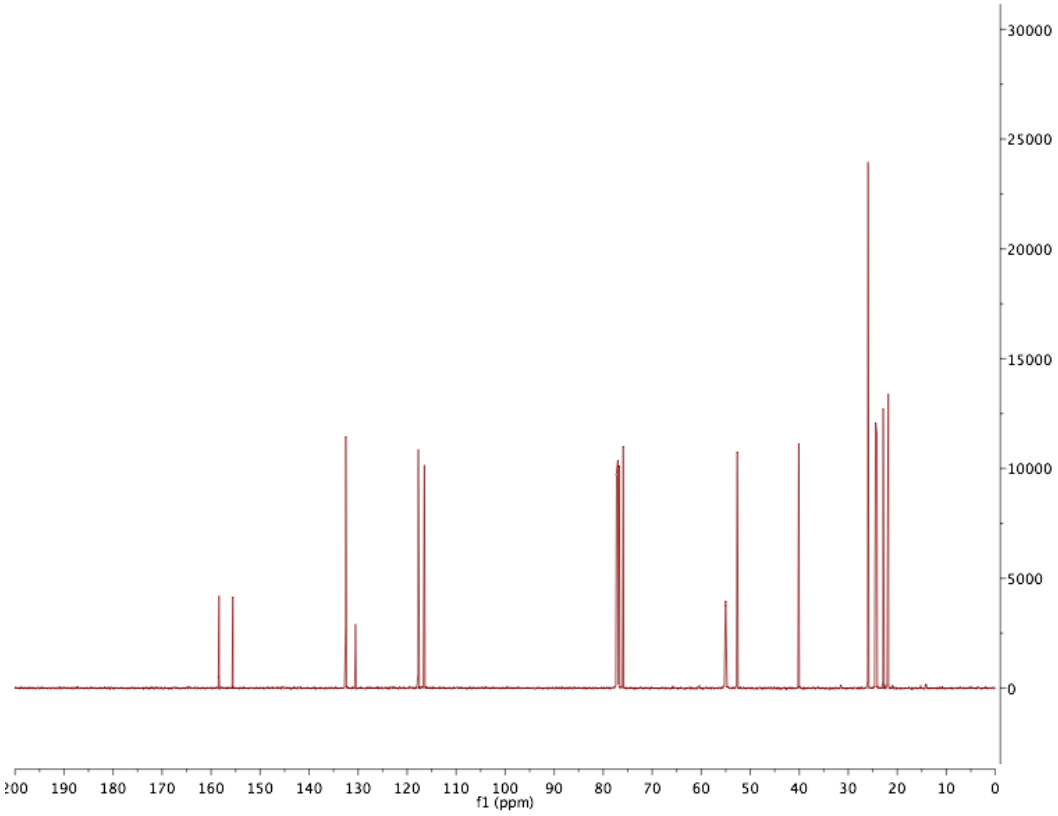

O
O
S
NH
CH3
F
O

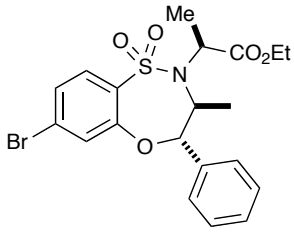
1E+05
1E+05
1E+05
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
-10000
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)


1E+05
1E+05
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
-10000
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

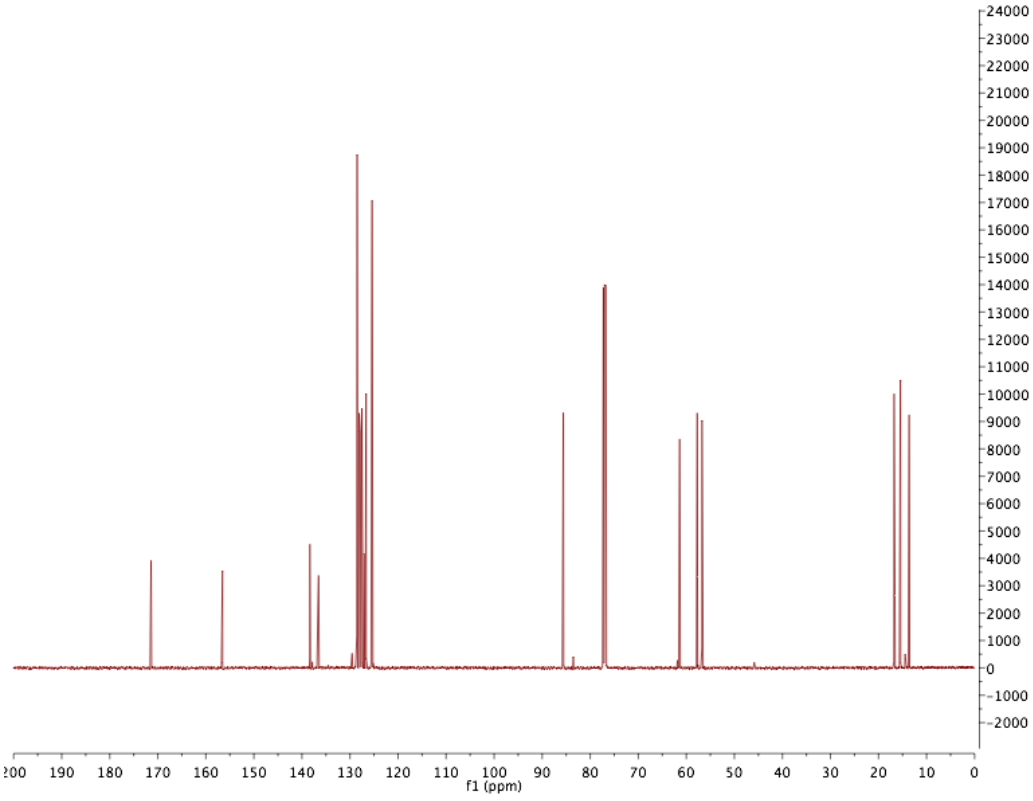

N
O
O
S
NH
O

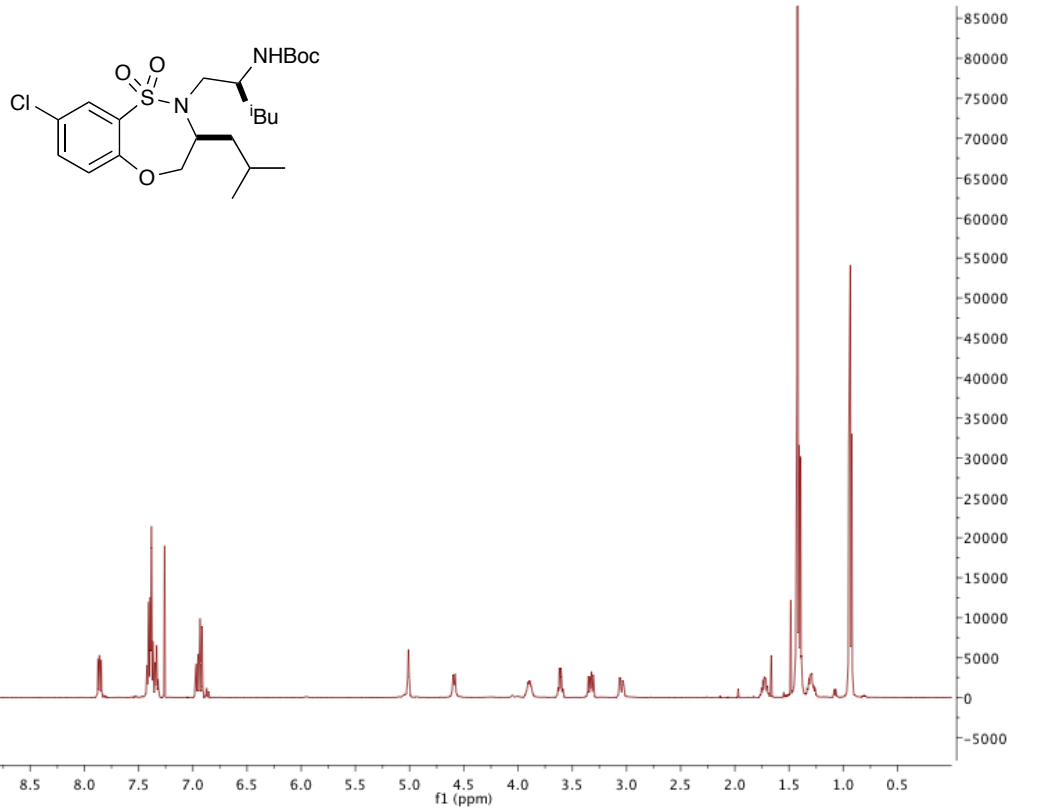
80000
75000
70000
65000
60000
55000
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
-5000
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)

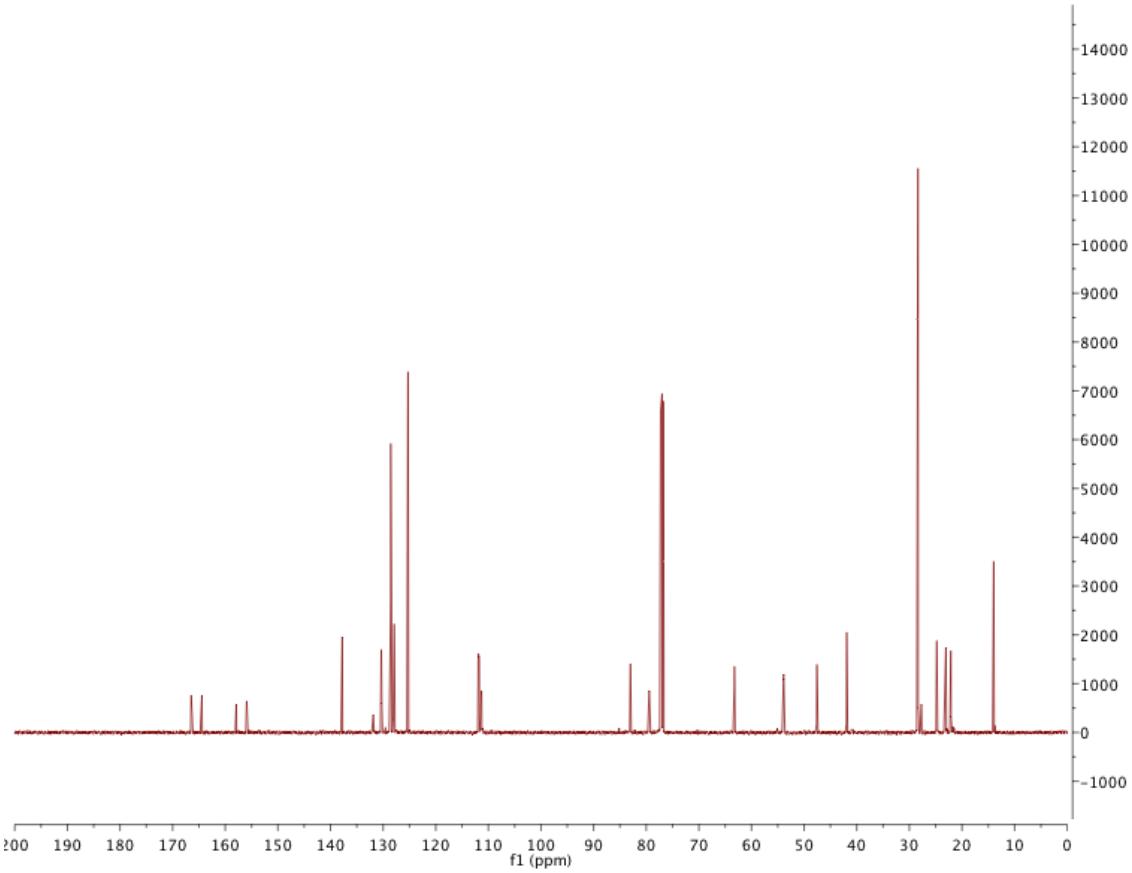

30000
25000
20000
15000
10000
5000
0
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

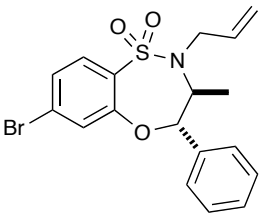

Me
O
O
S
N
CO2Et
Br
O

1E+05
1E+05
1E+05
1E+05
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
-10000
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

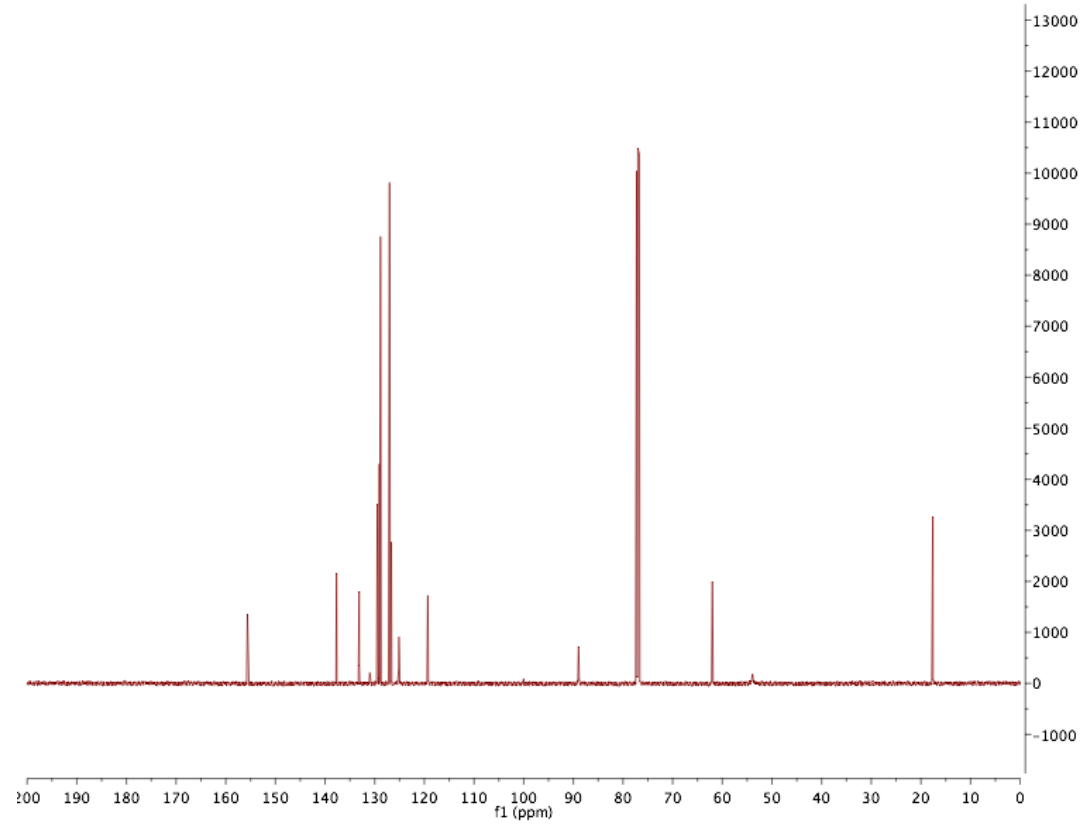

24000
23000
22000
21000
20000
19000
18000
17000
16000
15000
14000
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
-1000
-2000
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

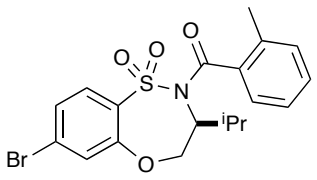

NHBoc
Cl
O
O
S
N
iBu
O
f1 (ppm)

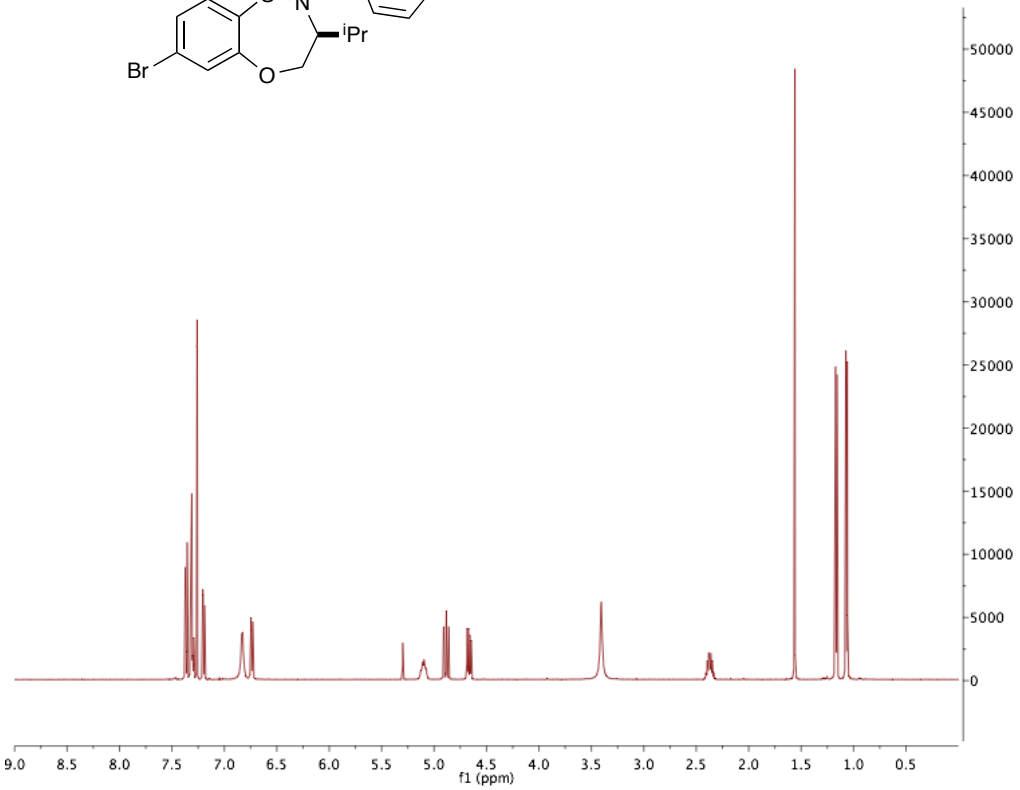

f1 (ppm)

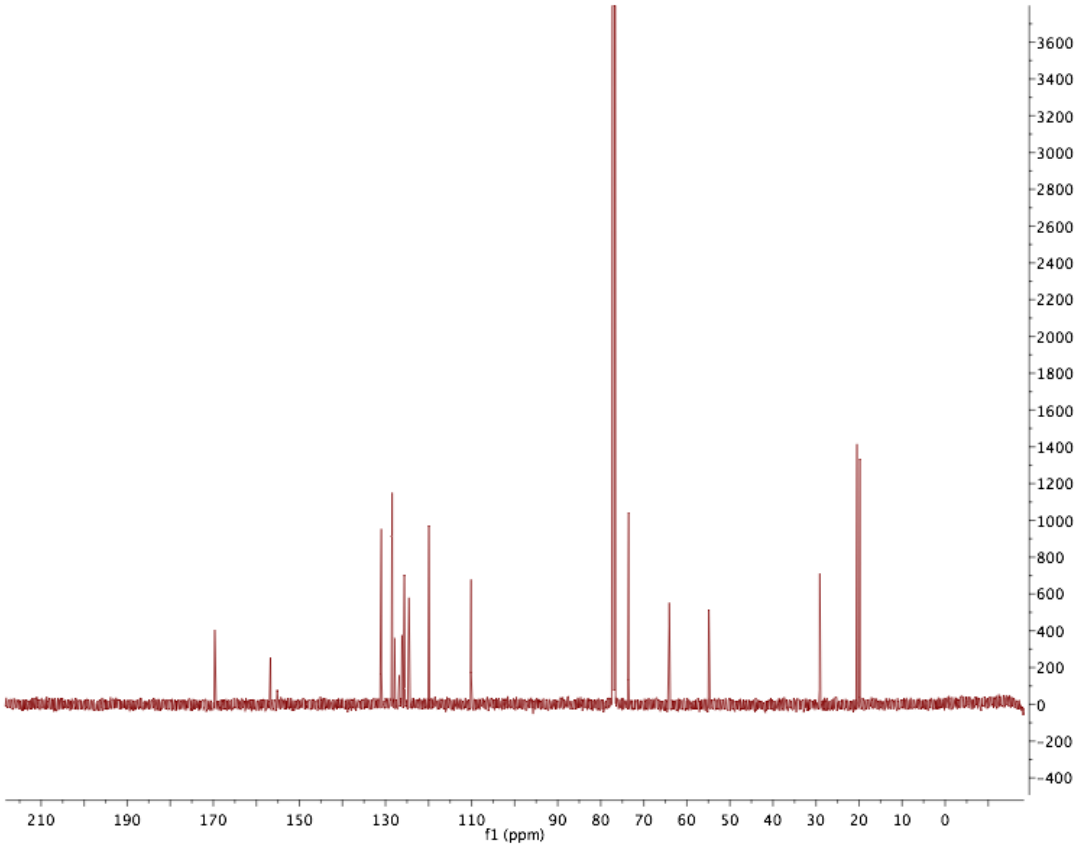

O
O
S
N
Br
O

90000
85000
80000
75000
70000
65000
60000
55000
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
-5000
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
f1 (ppm)


13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
-1000
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


O
O
S
N
O
iPr
Br
O


50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)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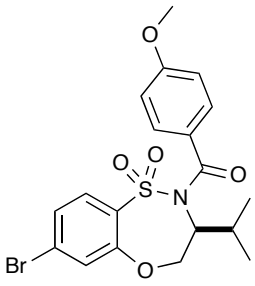
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0
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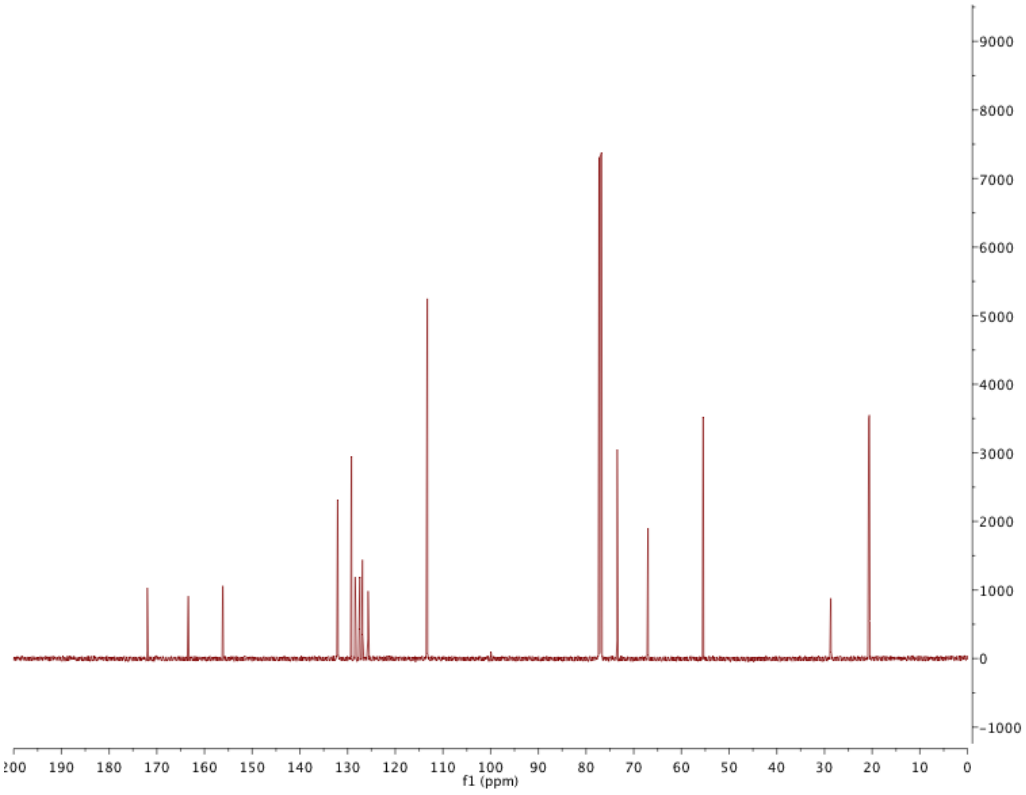
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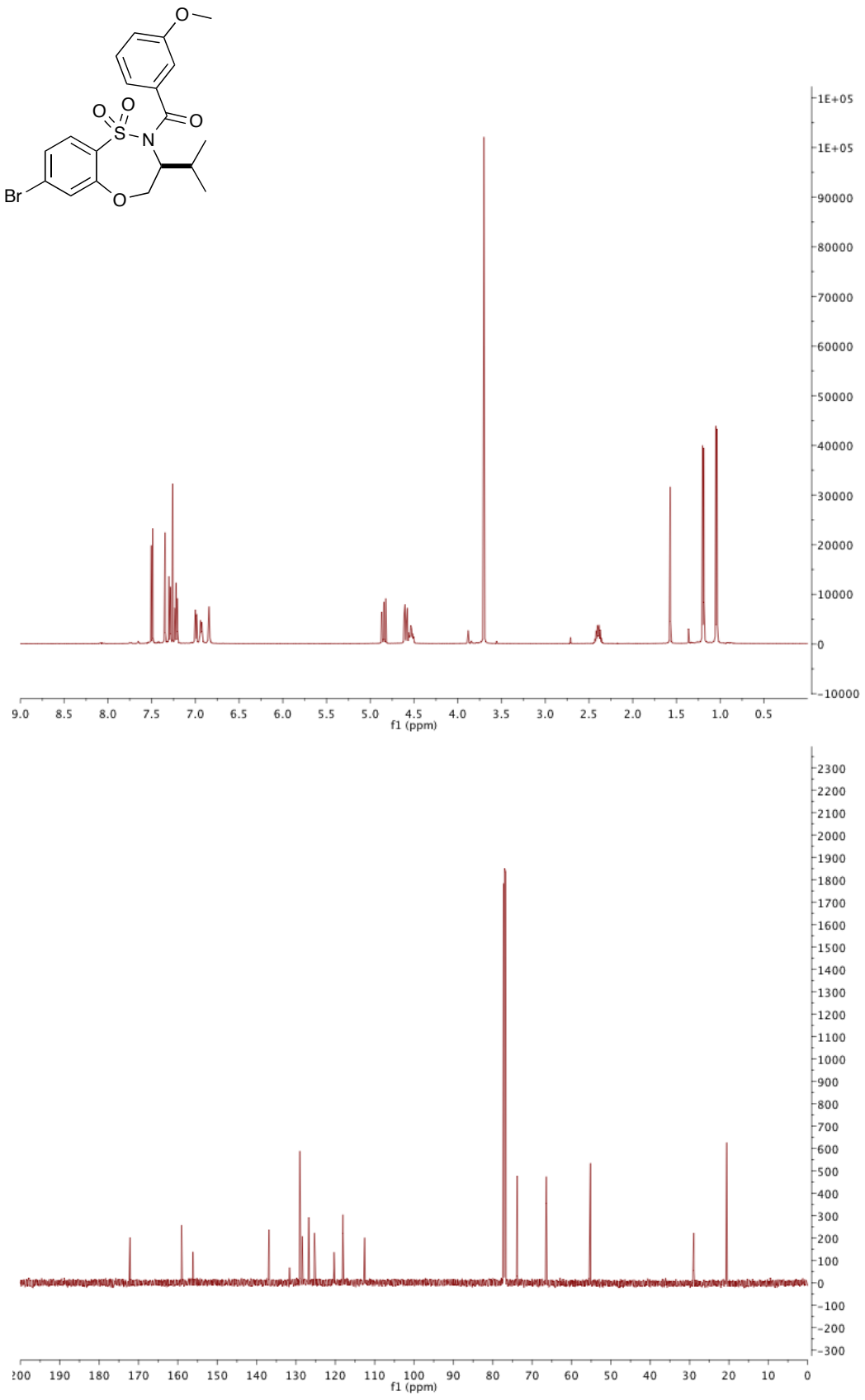
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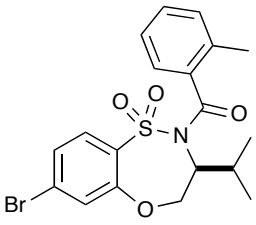
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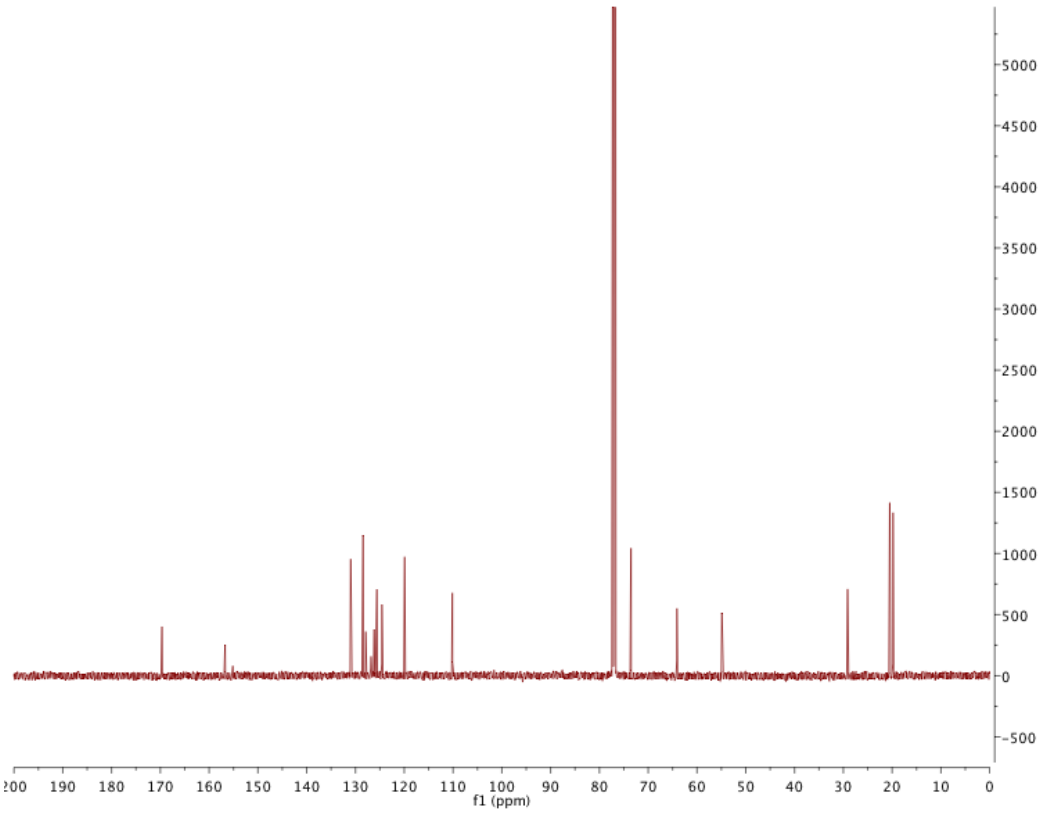
f1 (ppm)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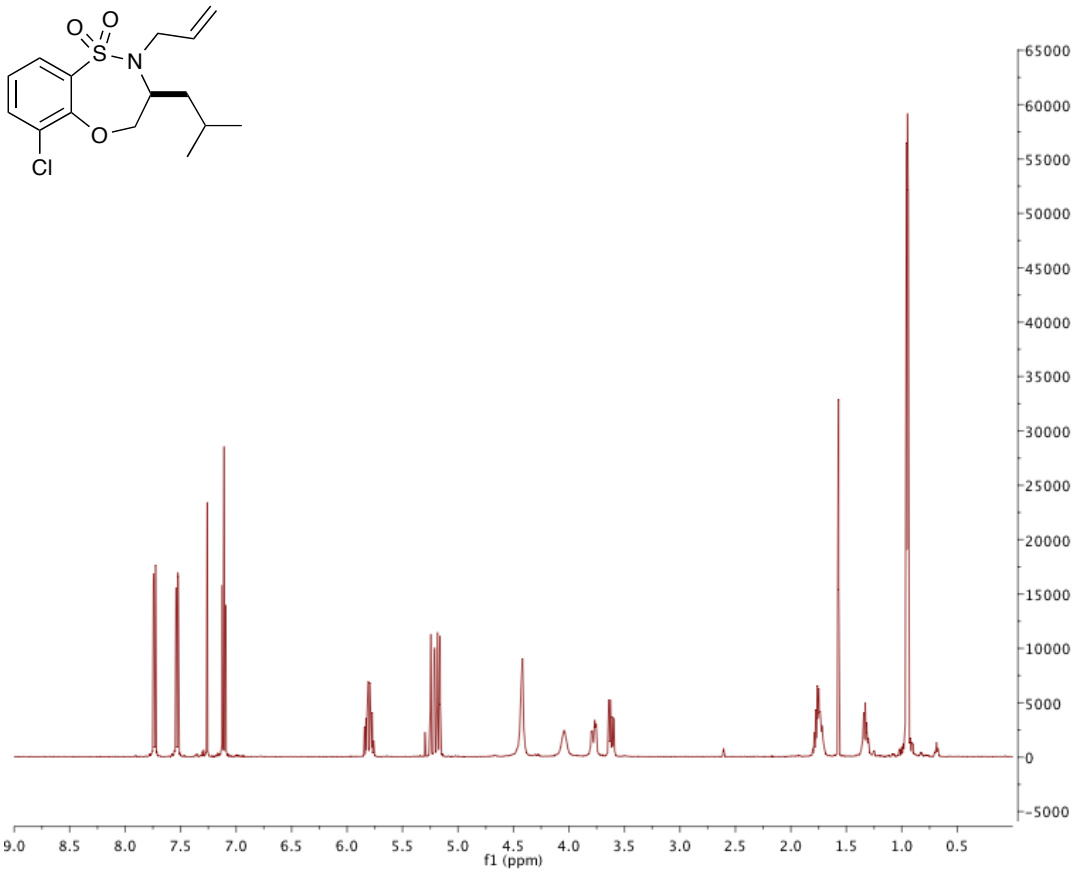
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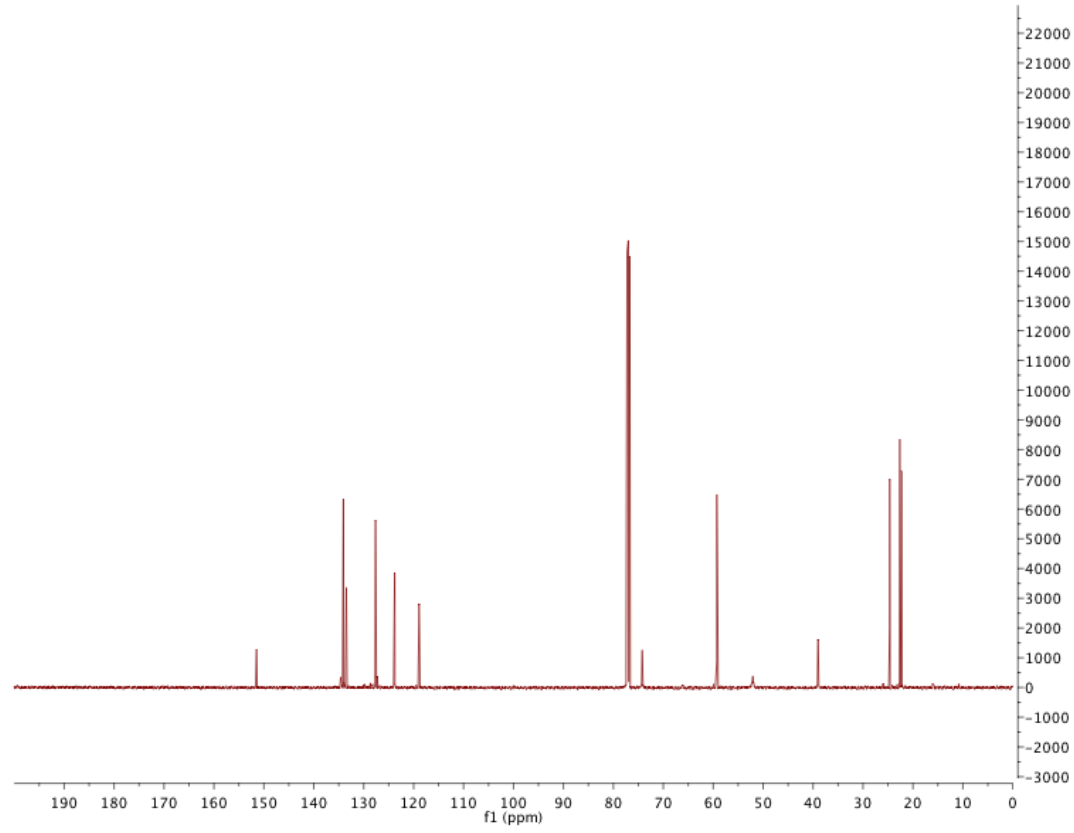
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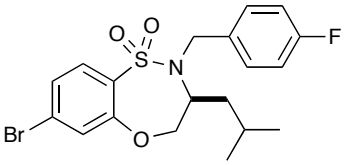
f1 (ppm)

275i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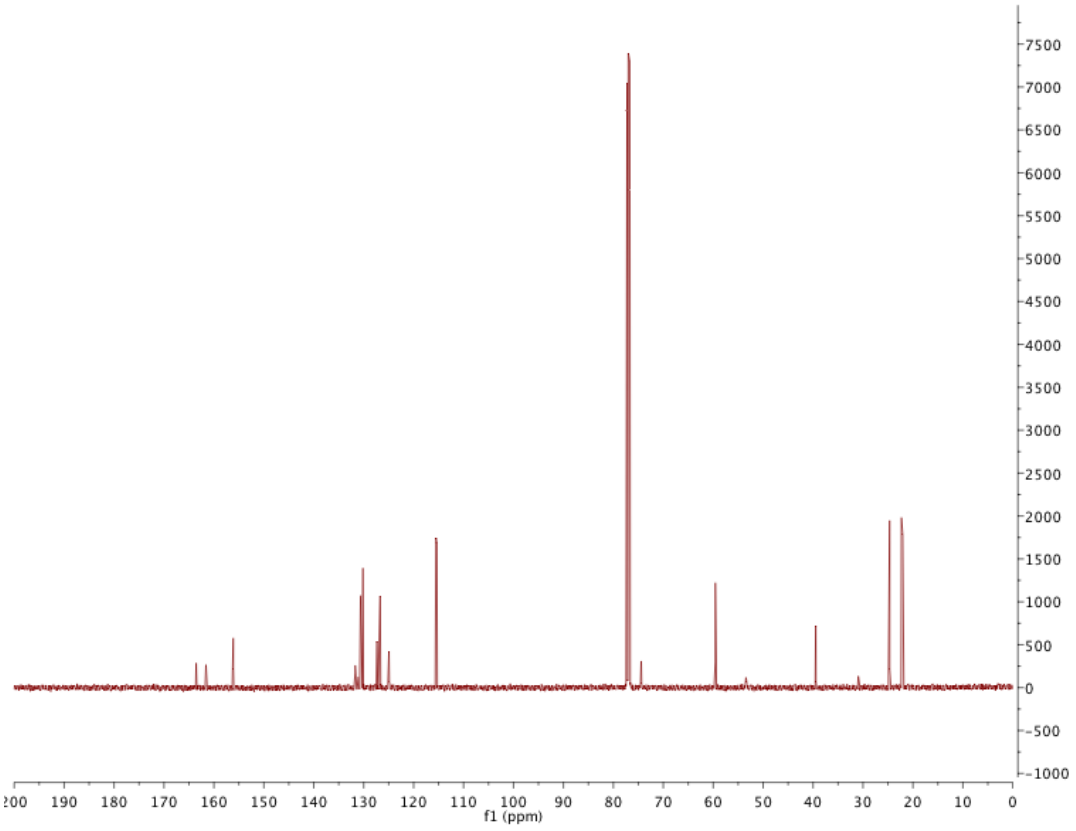
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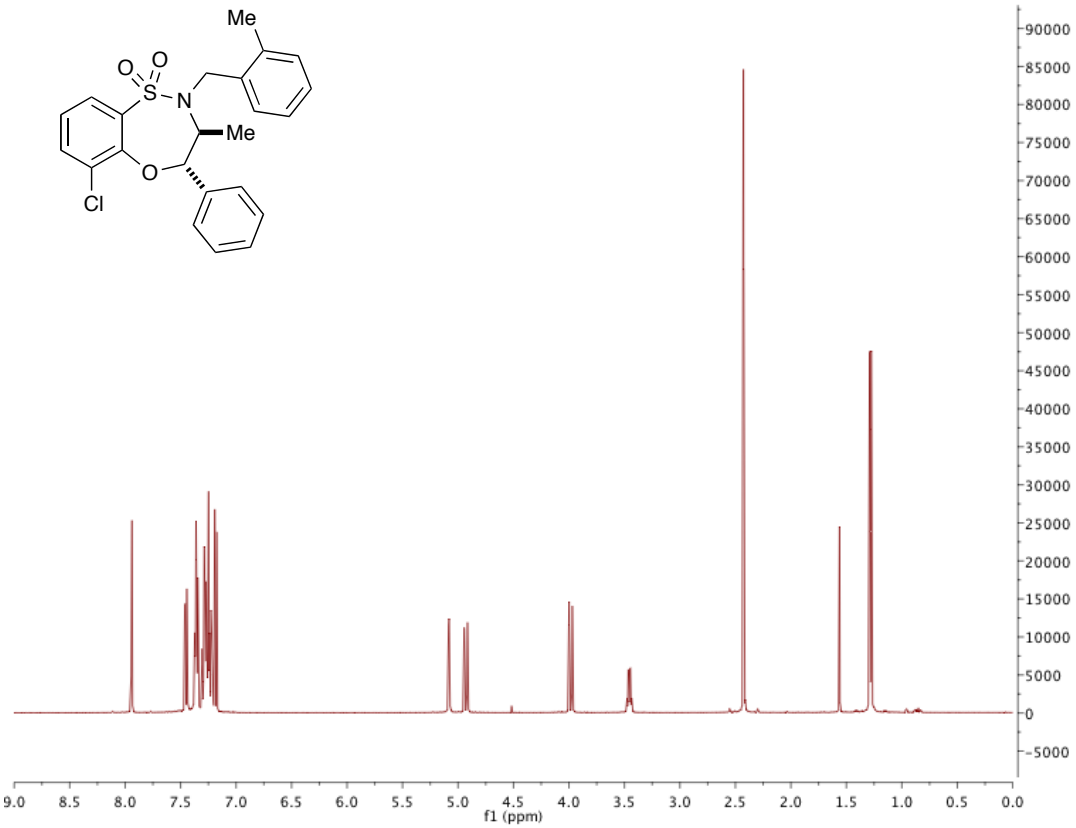
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-5000
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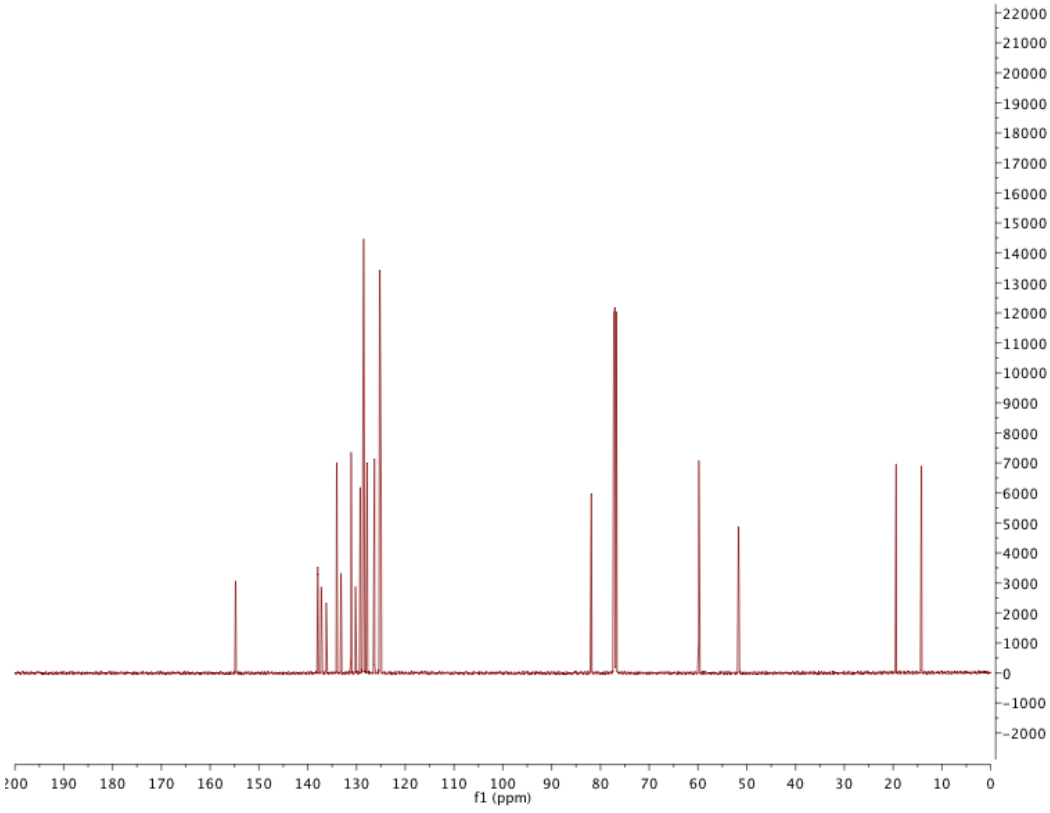
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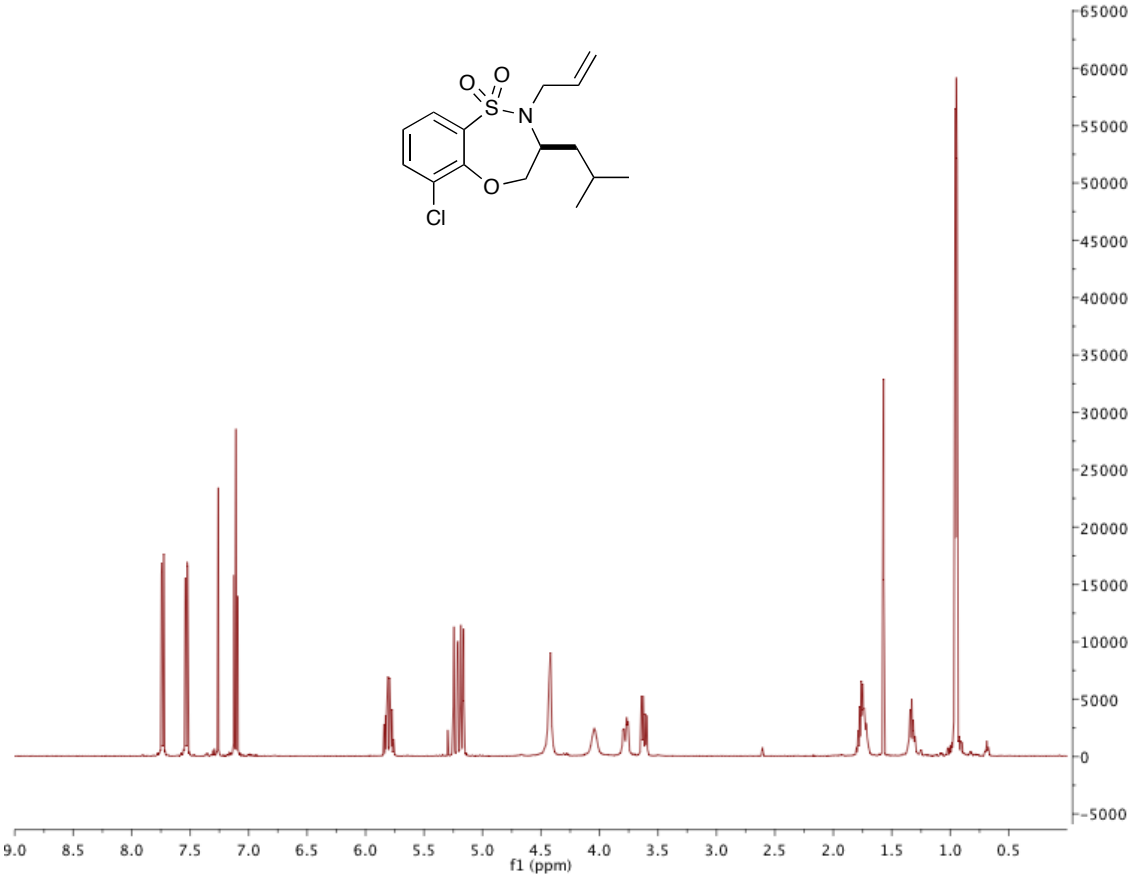
f1 (ppm)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6.0
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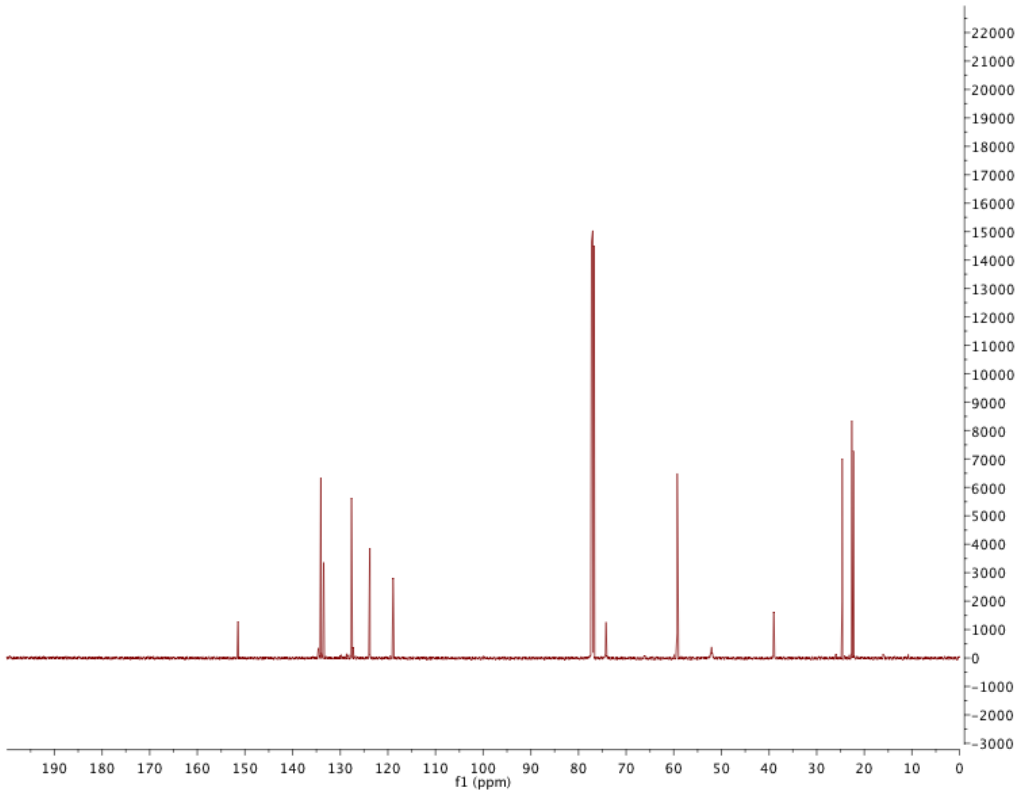
f1 (ppm)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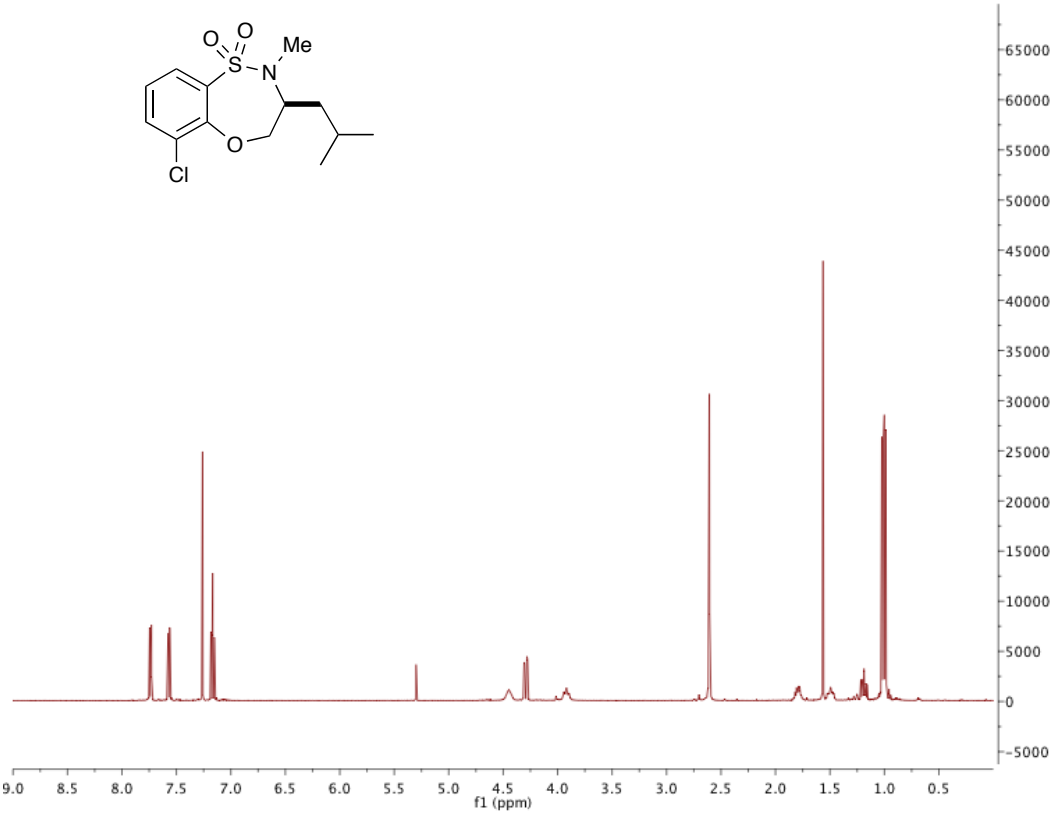
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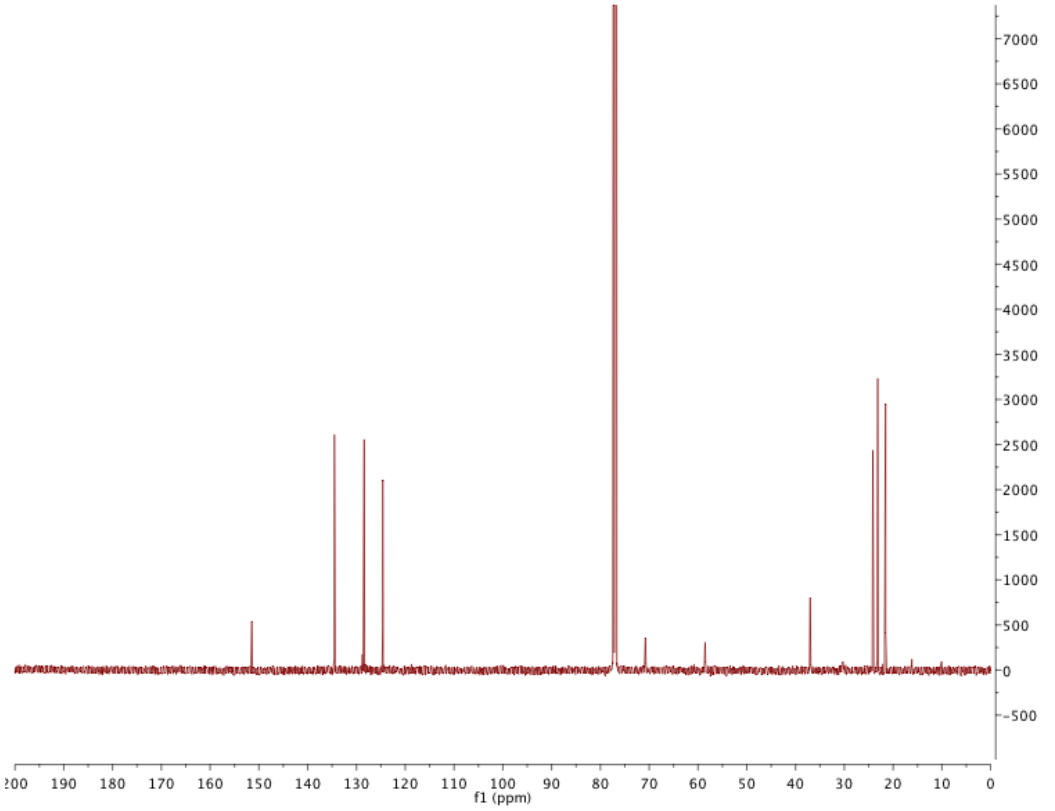
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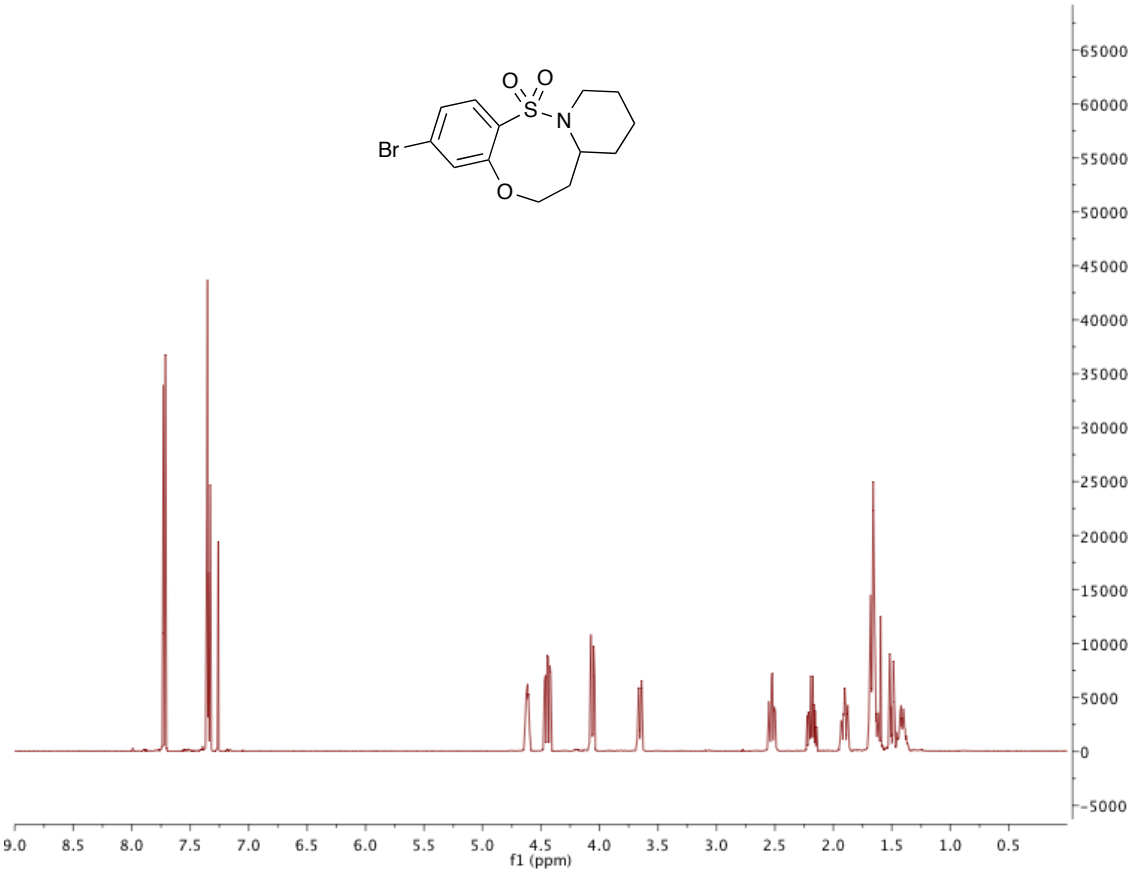
f1 (ppm)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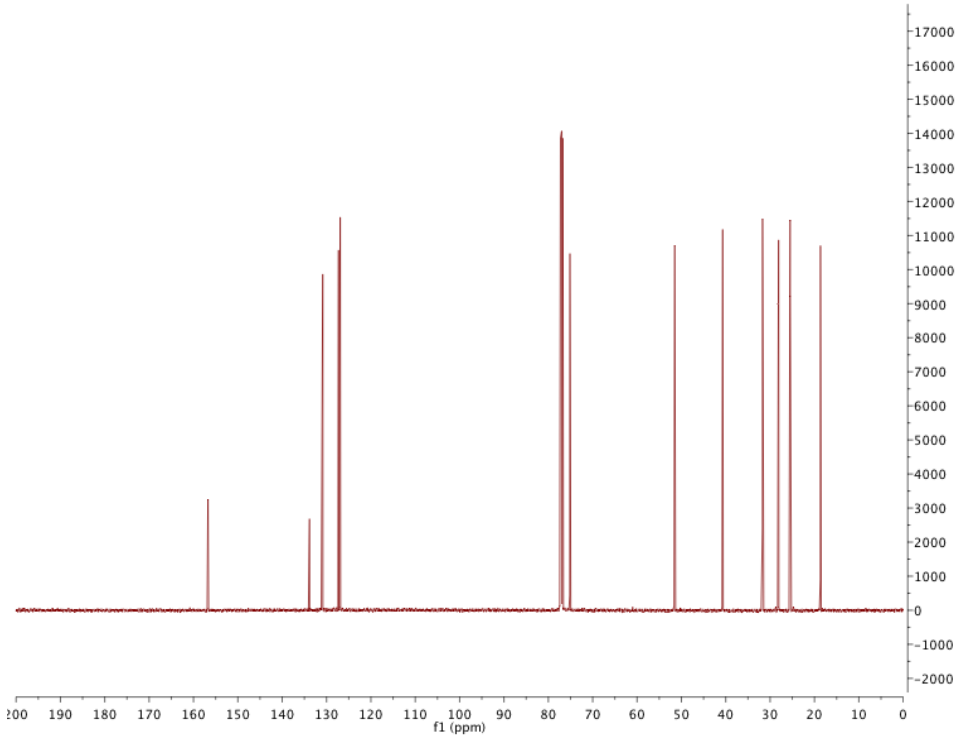
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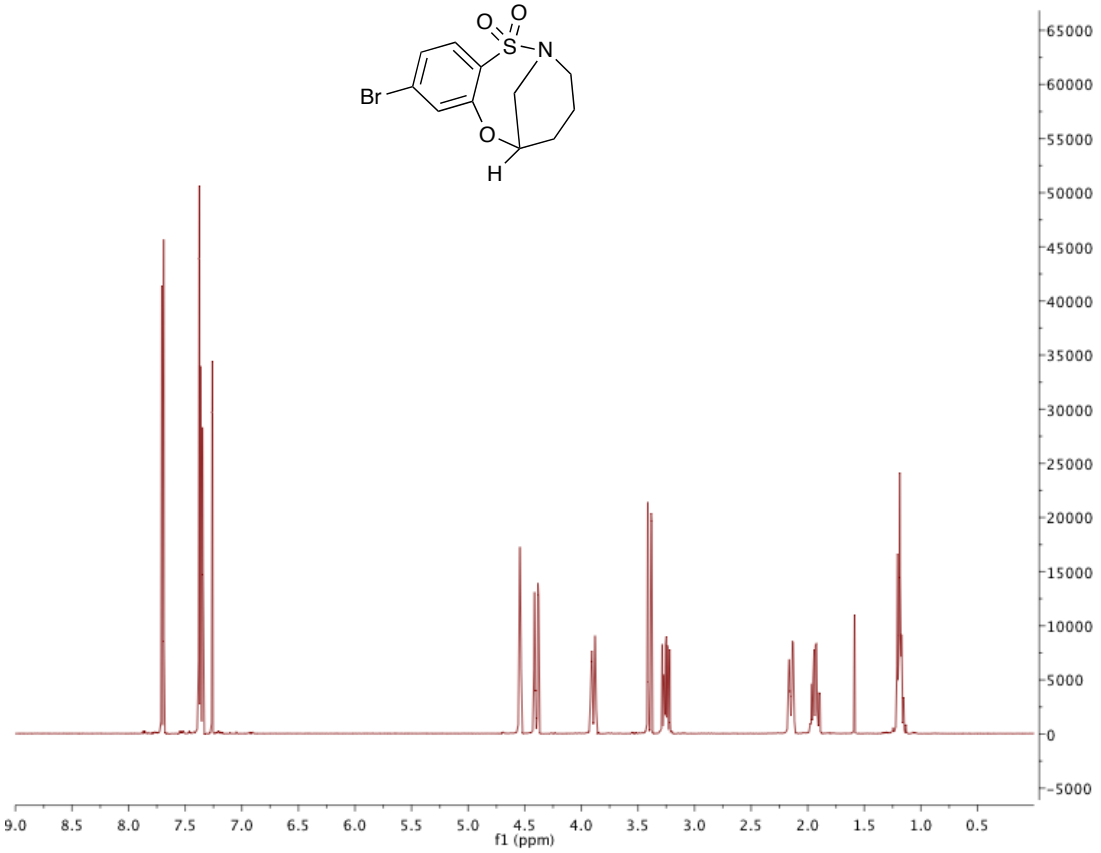
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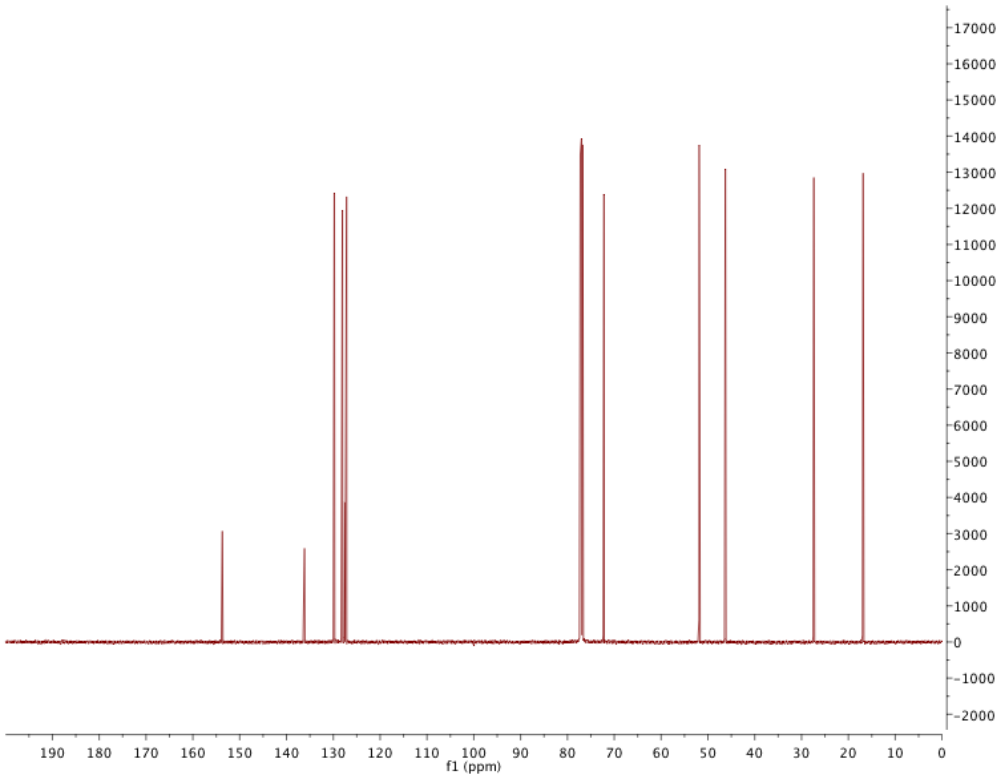
f1 (ppm)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190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

Appendix B
X-Ray Structure Reports

Crystal Structure Report

for

$C_{16}H_{14}BrNO_3S$

Compound 3.52f

Contents

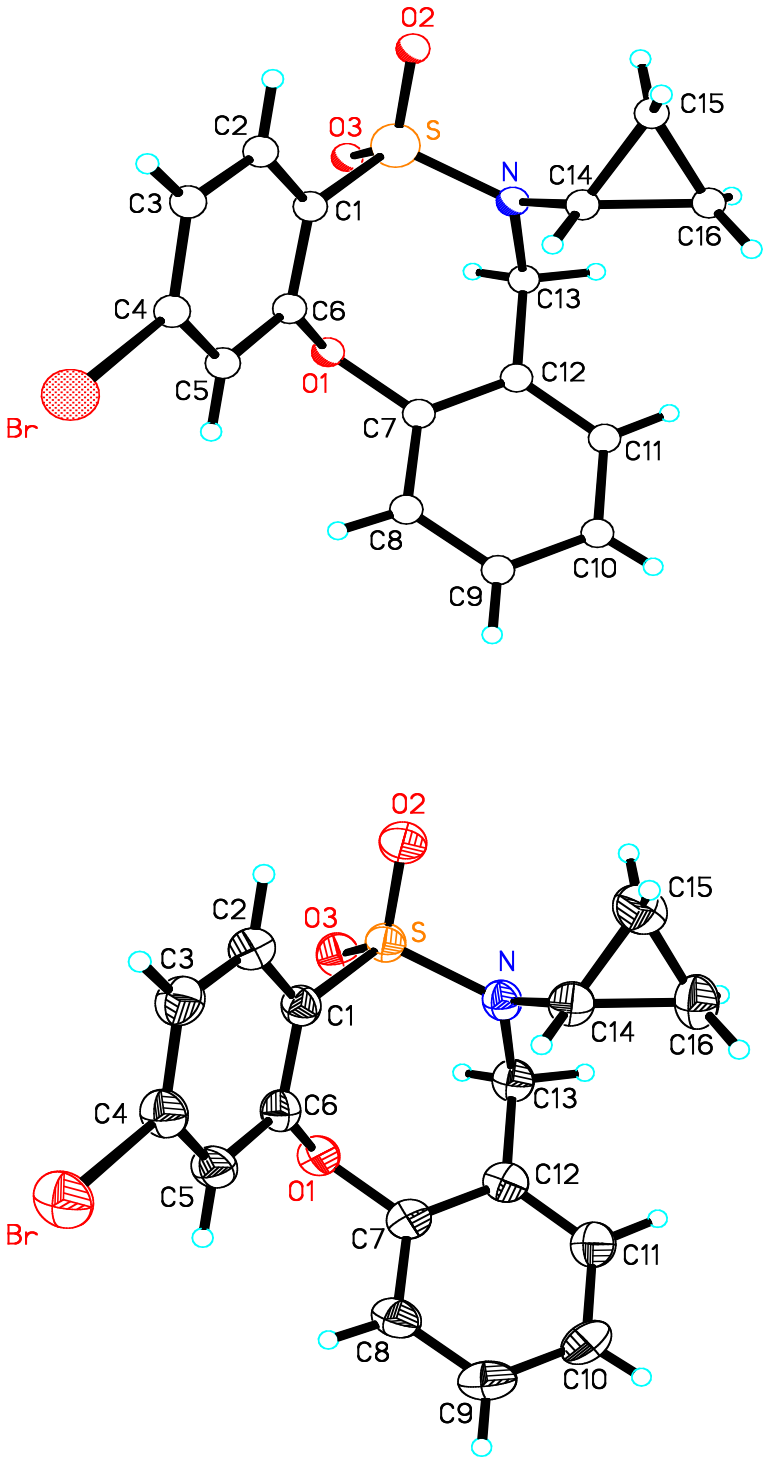
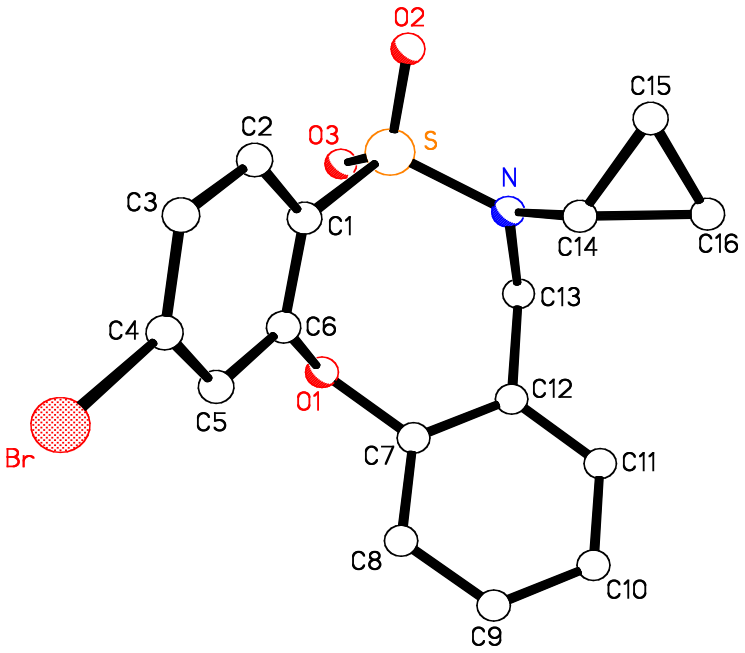


Figure 1. 50% Probability Ellipsoid Drawing of **3.52f**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C2
O3
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N
C3
C1
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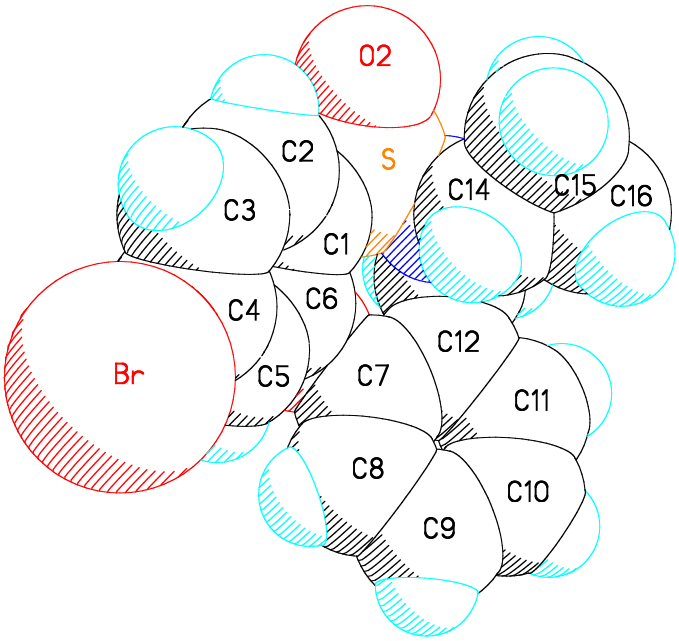
C16
C13
C4
C6
C12
O1
C5
Br
C7
C11
C8
C10
C9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C2
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C9

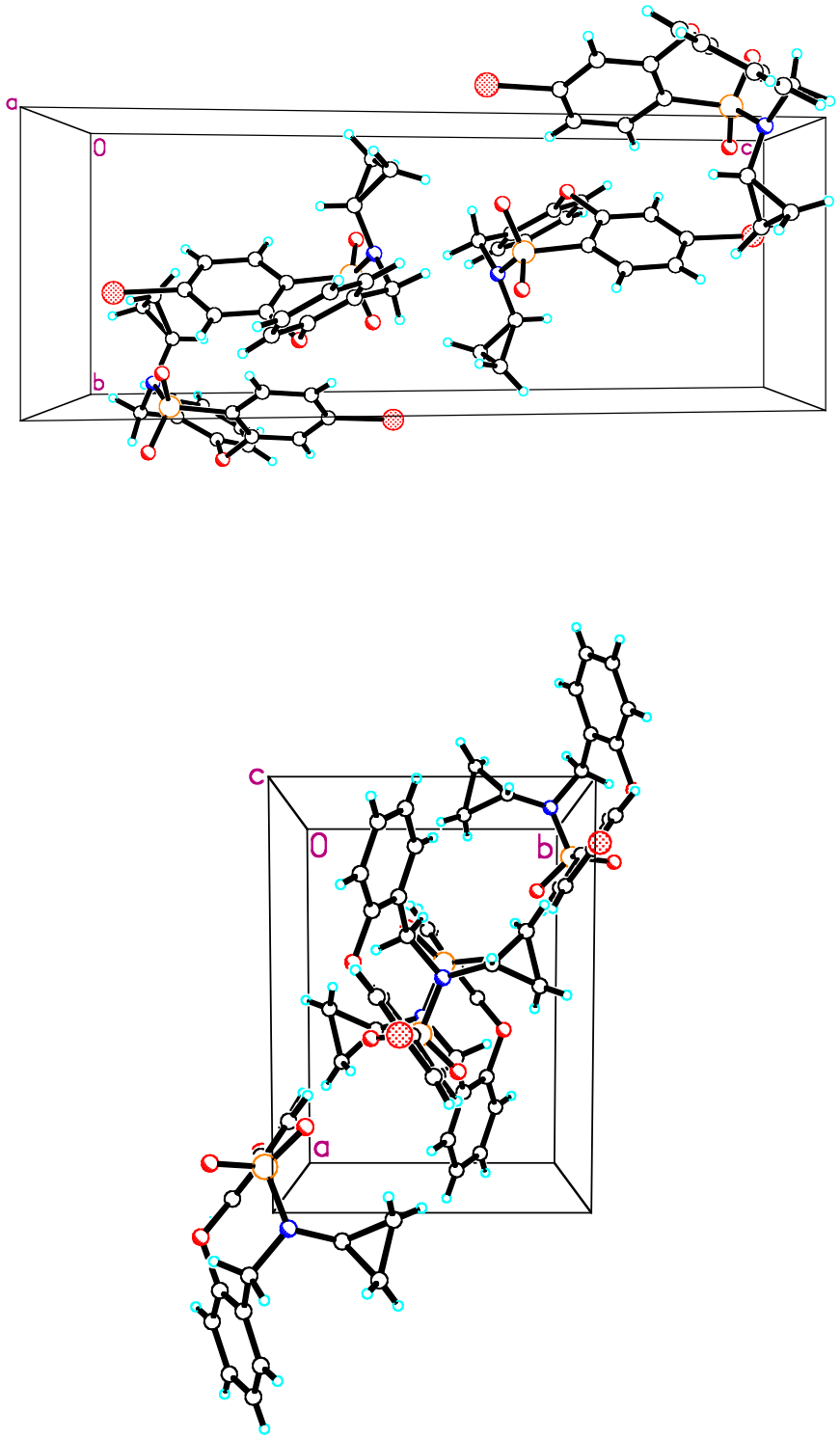

Figure 2. Packing diagram of **3.52f**

Comments

The asymmetric unit contains one $C_{16}H_{14}BrNO_3S$ molecule. All displacement ellipsoids are drawn at the 50% probability level.

Brief Experimental Description to be Included as Text or as a Footnote at Time of Publication

Parallelepiped-shaped crystals of $C_{16}H_{14}BrNO_3S$ are, at 100(2) K, monoclinic, space group $P2_1/n$ [an alternate setting of $P2_1/c - C_{2h}^5$ (No. 14)][(1)] with **a** = 10.252(2) Å, **b** = 7.471(2) Å, **c** = 20.115(4) Å, = 100.217(6), V = 1516.2(5) Å^3 and Z = 4 molecules {d_{calcd} = 1.666 g/cm^3; $_a$(CuK) = 5.092 mm^{-1}}. A full hemisphere of diffracted intensities (9343 6-second frames with a scan width of 0.50) was measured[(2)] for a single-domain specimen using monochromated CuK radiation (= 1.54178 Å) on a Bruker X8 Prospector Single Crystal Diffraction System equipped with Qazar MX optics, an APEXII CCD detector and an IS microfocus x-ray source operating at 45kV and 0.65mA. Lattice constants were determined with the Bruker SAINT software package using peak centers for 1432 reflections. A total of 17720 integrated reflection intensities having 2(CuK)< 130.41 were produced using the Bruker program SAINT[(3)]; 2527 of these were unique and gave R_{int} = 0.036 with a coverage which was 97.6% complete. The data were corrected empirically for variable absorption effects using equivalent reflections; the relative transmission factors ranged from 0.862 to 1.000. The Bruker software package SHELXTL was used to solve the structure using "direct methods" techniques. All stages of weighted full-matrix least-squares refinement were conducted using F_o^2 data with the SHELXTL Version 6.10 software package[(4)].

The final structural model incorporated anisotropic thermal parameters for all nonhydrogen atoms and isotropic thermal parameters for all hydrogen atoms. All hydrogen atoms were located in a difference Fourier and included in the structural model as independent isotropic atoms whose parameters were allowed to vary in least-squares refinement cycles. A total of 255 parameters were refined using no restraints, 2527 data and weights of $w = 1/ [^2(F^2) + (0.0428\ P)^2 + (2.8282\ P)]$, where $P = [F_o^2 + 2F_c^2] / 3$. Final agreement factors at convergence are: R_1(unweighted, based on F) = 0.037 for 2432 independent absorption-corrected "observed" reflections having 2(CuK)< 130.41 and I>2(I); R_1(unweighted, based on F) = 0.037 and wR_2(weighted, based on F^2) = 0.091 for all 2527 independent absorption-corrected reflections having 2(CuK)< 130.41. The largest shift/s.u. was 0.000 in the final refinement cycle. The final difference map had maxima and minima of 1.38 and -0.52 e$^-$/Å^3, respectively.

Acknowledgment

The authors thank the University of Kansas for funds to purchase the computers.

References

(1) International **Table** s for Crystallography, Vol A, 4th ed., Kluwer: Boston (1996).

(2) Data Collection: SMART Software Reference Manual (1998). Bruker-AXS, 5465 E. Cheryl Parkway, Madison, WI 53711-5373 USA.

(3) Data Reduction: SAINT Software Reference Manual (1998). Bruker-AXS, 6300 Enterprise Dr., Madison, WI 53719-1173, USA.

(4) G. M. Sheldrick (2000). SHELXTL Version 6.10 Reference Manual. Bruker-AXS, 5465 E. Cheryl Parkway, Madison, WI 53711-5373 USA.

Table 1. Crystal data and structure refinement for $C_{16}H_{14}BrNO_3S$.

Empirical formula	$C_{16}H_{14}BrNO_3S$	
Formula weight	380.25	
Temperature	100(2) K	
Wavelength	1.54178 Å	
Crystal system	Monoclinic	
Space group	$P2_1/n$ [an alternate setting of $P2_1/c - C_{2h}^5$ (No. 14)]	
Unit cell dimensions	**a** = 10.252(2) Å	= 90.000°
	b = 7.471(2) Å	= 100.217(6)°
	c = 20.115(4) Å	= 90.000°
Volume	1516.2(5) $Å^3$	
Z	4	
Density (calculated)	1.666 Mg/m^3	
Absorption coefficient	5.092 mm^{-1}	
F(000)	768	
Crystal size	0.11 x 0.06 x 0.05 mm^3	
Theta range for data collection	4.47° to 65.21°	
Index ranges	-11 h 9, -8 k 8, -23 l 23	
Reflections collected	17720	
Independent reflections	2527 [R_{int} = 0.036]	
Completeness to theta = 65.21°	97.6 %	
Absorption correction	Multi-scan	
Max. and min. transmission	1.000 and 0.892	
Refinement method	Full-matrix least-squares on F^2	
Data / restraints / parameters	2527 / 0 / 255	
Goodness-of-fit on F^2	1.063	
Final R indices [I>2sigma(I)]	R_1 = 0.037, wR_2 = 0.091	
R indices (all data)	R_1 = 0.037, wR_2 = 0.091	
Largest diff. peak and hole	1.38 and -0.52 $e^-/Å^3$	

$R_1 = \| |F_o| - |F_c| \| / |F_o|$

$wR_2 = \{ [w(F_o^2 - F_c^2)^2] / [w(F_o^2)^2] \}^{1/2}$

Table 2. Atomic coordinates (x 10^4) and equivalent isotropic displacement parameters ($Å^2$x 10^3) for $C_{16}H_{14}BrNO_3S$. U(eq) is defined as one third of the trace of the orthogonalized U_{ij} tensor.

_	x	y	z	U(eq)
Br	4125(1)	6033(1)	637(1)	40(1)
S	4063(1)	5423(1)	3822(1)	27(1)
O(1)	5887(2)	7684(3)	3173(1)	28(1)
O(2)	3095(2)	4099(3)	3869(1)	35(1)
O(3)	3943(2)	7144(3)	4116(1)	33(1)
N	5516(2)	4634(3)	4156(1)	27(1)
C(1)	4045(3)	5680(4)	2939(1)	26(1)
C(2)	3078(3)	4825(4)	2475(2)	30(1)
C(3)	3077(3)	4954(4)	1788(2)	32(1)
C(4)	4061(3)	5926(4)	1574(2)	30(1)
C(5)	5021(3)	6824(4)	2020(2)	29(1)
C(6)	5003(3)	6708(4)	2707(1)	27(1)
C(7)	7196(3)	7043(4)	3324(1)	28(1)
C(8)	8073(3)	7405(5)	2897(2)	33(1)
C(9)	9368(3)	6815(5)	3074(2)	39(1)
C(10)	9775(3)	5910(5)	3680(2)	38(1)
C(11)	8881(3)	5585(5)	4102(2)	35(1)
C(12)	7576(3)	6158(4)	3936(2)	29(1)
C(13)	6609(3)	5874(4)	4411(2)	30(1)
C(14)	5870(3)	2926(4)	3900(2)	30(1)
C(15)	5304(4)	1245(5)	4126(2)	41(1)
C(16)	6724(4)	1699(5)	4386(2)	39(1)

Table 3. Bond lengths [Å] for $C_{16}H_{14}BrNO_3S$.

Br-C(4)	1.900(3)
S-O(2)	1.417(2)
S-O(3)	1.429(2)
S-N	1.632(2)
S-C(1)	1.783(3)
O(1)-C(6)	1.389(4)
O(1)-C(7)	1.406(4)
N-C(14)	1.446(4)
N-C(13)	1.474(4)
C(1)-C(2)	1.390(4)
C(1)-C(6)	1.391(4)
C(2)-C(3)	1.385(4)
C(2)-H(2)	0.93(4)
C(3)-C(4)	1.373(5)
C(3)-H(3)	0.89(4)
C(4)-C(5)	1.382(5)
C(5)-C(6)	1.389(4)
C(5)-H(5)	0.92(4)
C(7)-C(8)	1.376(4)
C(7)-C(12)	1.391(4)
C(8)-C(9)	1.384(5)
C(8)-H(8)	0.89(4)
C(9)-C(10)	1.392(5)
C(9)-H(9)	0.90(4)
C(10)-C(11)	1.377(5)
C(10)-H(10)	0.83(4)
C(11)-C(12)	1.388(5)
C(11)-H(11)	0.97(4)
C(12)-C(13)	1.510(4)
C(13)-H(13A)	1.02(4)
C(13)-H(13B)	0.94(3)
C(14)-C(15)	1.488(5)
C(14)-C(16)	1.503(5)
C(14)-H(14)	0.93(4)

C(15)-C(16)	1.496(6)
C(15)-H(15A)	0.92(4)
C(15)-H(15B)	0.93(4)
C(16)-H(16A)	0.97(4)
C(16)-H(16B)	0.95(4)

Table 4. Bond angles [°] for $C_{16}H_{14}BrNO_3S$.

O(2)-S-O(3)	119.2(1)
O(2)-S-N	108.6(1)
O(3)-S-N	107.1(1)
O(2)-S-C(1)	105.0(1)
O(3)-S-C(1)	109.2(1)
N-S-C(1)	107.3(1)
C(6)-O(1)-C(7)	116.8(2)
C(14)-N-C(13)	117.0(2)
C(14)-N-S	116.1(2)
C(13)-N-S	119.9(2)
C(2)-C(1)-C(6)	119.4(3)
C(2)-C(1)-S	120.0(2)
C(6)-C(1)-S	120.7(2)
C(3)-C(2)-C(1)	120.8(3)
C(3)-C(2)-H(2)	119(2)
C(1)-C(2)-H(2)	120(2)
C(4)-C(3)-C(2)	118.6(3)
C(4)-C(3)-H(3)	120(2)
C(2)-C(3)-H(3)	121(2)
C(3)-C(4)-C(5)	122.1(3)
C(3)-C(4)-Br	119.4(2)
C(5)-C(4)-Br	118.5(2)
C(4)-C(5)-C(6)	118.8(3)
C(4)-C(5)-H(5)	123(2)
C(6)-C(5)-H(5)	118(2)
O(1)-C(6)-C(5)	121.1(3)
O(1)-C(6)-C(1)	118.6(2)
C(5)-C(6)-C(1)	120.2(3)
C(8)-C(7)-C(12)	122.3(3)
C(8)-C(7)-O(1)	120.2(3)
C(12)-C(7)-O(1)	117.4(3)
C(7)-C(8)-C(9)	118.7(3)
C(7)-C(8)-H(8)	118(2)
C(9)-C(8)-H(8)	123(2)

C(8)-C(9)-C(10)	120.3(3)
C(8)-C(9)-H(9)	120(3)
C(10)-C(9)-H(9)	120(3)
C(11)-C(10)-C(9)	119.8(3)
C(11)-C(10)-H(10)	117(3)
C(9)-C(10)-H(10)	123(3)
C(10)-C(11)-C(12)	121.0(3)
C(10)-C(11)-H(11)	121(2)
C(12)-C(11)-H(11)	117(2)
C(11)-C(12)-C(7)	117.8(3)
C(11)-C(12)-C(13)	121.2(3)
C(7)-C(12)-C(13)	121.0(3)
N-C(13)-C(12)	114.3(2)
N-C(13)-H(13A)	107(2)
C(12)-C(13)-H(13A)	108(2)
N-C(13)-H(13B)	108(2)
C(12)-C(13)-H(13B)	110(2)
H(13A)-C(13)-H(13B)	110(3)
N-C(14)-C(15)	120.0(3)
N-C(14)-C(16)	117.4(3)
C(15)-C(14)-C(16)	60.0(2)
N-C(14)-H(14)	114(2)
C(15)-C(14)-H(14)	117(2)
C(16)-C(14)-H(14)	119(2)
C(14)-C(15)-C(16)	60.5(2)
C(14)-C(15)-H(15A)	115(3)
C(16)-C(15)-H(15A)	117(3)
C(14)-C(15)-H(15B)	118(2)
C(16)-C(15)-H(15B)	122(2)
H(15A)-C(15)-H(15B)	114(4)
C(15)-C(16)-C(14)	59.5(2)
C(15)-C(16)-H(16A)	117(2)
C(14)-C(16)-H(16A)	112(2)
C(15)-C(16)-H(16B)	117(2)
C(14)-C(16)-H(16B)	118(2)
H(16A)-C(16)-H(16B)	119(3)

Table 5. Anisotropic displacement parameters ($Å^2 x\ 10^3$) for $C_{16}H_{14}BrNO_3S$. The anisotropic displacement factor exponent takes the form: $-2^2[\ h^2\ a^{*2}U_{11} + ...\ + 2\ h\ k\ a^*\ b^*\ U_{12}\ ]$

	U_{11}	U_{22}	U_{33}	U_{23}	U_{13}	U_{12}
Br	49(1)	49(1)	21(1)	-5(1)	5(1)	-2(1)
S	28(1)	32(1)	23(1)	2(1)	8(1)	5(1)
O(1)	30(1)	29(1)	24(1)	-2(1)	4(1)	0(1)
O(2)	34(1)	41(1)	32(1)	5(1)	11(1)	3(1)
O(3)	39(1)	34(1)	30(1)	0(1)	11(1)	9(1)
N	31(1)	28(1)	23(1)	1(1)	6(1)	4(1)
C(1)	28(2)	30(2)	21(1)	2(1)	5(1)	4(1)
C(2)	27(2)	31(2)	31(2)	0(1)	5(1)	-1(1)
C(3)	31(2)	34(2)	30(2)	-3(1)	-1(1)	-1(1)
C(4)	36(2)	33(2)	22(2)	-2(1)	5(1)	3(1)
C(5)	31(2)	33(2)	24(2)	1(1)	6(1)	-1(1)
C(6)	29(2)	27(2)	24(1)	0(1)	3(1)	3(1)
C(7)	28(2)	28(2)	26(2)	-6(1)	3(1)	-3(1)
C(8)	35(2)	38(2)	27(2)	1(1)	4(1)	-9(1)
C(9)	33(2)	50(2)	37(2)	-6(2)	10(1)	-10(2)
C(10)	23(2)	45(2)	43(2)	-7(2)	1(1)	0(1)
C(11)	36(2)	35(2)	31(2)	-2(1)	2(1)	0(1)
C(12)	32(2)	30(2)	25(2)	-4(1)	3(1)	-4(1)
C(13)	35(2)	33(2)	22(2)	-2(1)	4(1)	3(1)
C(14)	34(2)	35(2)	23(2)	-2(1)	9(1)	6(1)
C(15)	51(2)	31(2)	46(2)	-1(2)	20(2)	4(2)
C(16)	49(2)	39(2)	31(2)	2(2)	9(2)	14(2)

Table 6. Hydrogen coordinates (x 10^4) and isotropic displacement parameters (Å^{2}x 10^3)
for $C_{16}H_{14}BrNO_3S$.

	x	y	z	U(eq)
H(2)	2420(40)	4160(50)	2625(19)	38(10)
H(3)	2430(30)	4450(50)	1488(17)	27(8)
H(5)	5670(30)	7510(50)	1883(17)	33(9)
H(8)	7780(30)	8030(50)	2522(19)	32(9)
H(9)	9950(40)	7040(50)	2800(20)	48(11)
H(10)	10540(40)	5540(50)	3800(20)	41(10)
H(11)	9140(30)	4980(50)	4530(19)	38(9)
H(13A)	7110(40)	5330(50)	4850(20)	43(10)
H(13B)	6240(30)	6980(50)	4507(16)	24(8)
H(14)	6000(30)	2970(50)	3455(18)	32(9)
H(15A)	4710(40)	1390(50)	4420(20)	47(11)
H(15B)	5060(40)	340(60)	3810(20)	43(10)
H(16A)	7390(30)	1100(40)	4178(18)	30(9)
H(16B)	6950(40)	2060(50)	4850(20)	40(10)

Table 7. Torsion angles [°] for $C_{16}H_{14}BrNO_3S$.

O(2)-S-N-C(14)	53.3(2)
O(3)-S-N-C(14)	-176.9(2)
C(1)-S-N-C(14)	-59.7(2)
O(2)-S-N-C(13)	-156.8(2)
O(3)-S-N-C(13)	-26.9(2)
C(1)-S-N-C(13)	90.3(2)
O(2)-S-C(1)-C(2)	7.7(3)
O(3)-S-C(1)-C(2)	-121.1(3)
N-S-C(1)-C(2)	123.1(2)
O(2)-S-C(1)-C(6)	-171.3(2)
O(3)-S-C(1)-C(6)	59.8(3)
N-S-C(1)-C(6)	-55.9(3)
C(6)-C(1)-C(2)-C(3)	1.5(5)
S-C(1)-C(2)-C(3)	-177.6(2)
C(1)-C(2)-C(3)-C(4)	0.8(5)
C(2)-C(3)-C(4)-C(5)	-2.3(5)
C(2)-C(3)-C(4)-Br	177.2(2)
C(3)-C(4)-C(5)-C(6)	1.4(5)
Br-C(4)-C(5)-C(6)	-178.1(2)
C(7)-O(1)-C(6)-C(5)	-76.6(3)
C(7)-O(1)-C(6)-C(1)	106.9(3)
C(4)-C(5)-C(6)-O(1)	-175.5(3)
C(4)-C(5)-C(6)-C(1)	1.0(5)
C(2)-C(1)-C(6)-O(1)	174.2(3)
S-C(1)-C(6)-O(1)	-6.8(4)
C(2)-C(1)-C(6)-C(5)	-2.4(4)
S-C(1)-C(6)-C(5)	176.7(2)
C(6)-O(1)-C(7)-C(8)	80.7(3)
C(6)-O(1)-C(7)-C(12)	-103.6(3)
C(12)-C(7)-C(8)-C(9)	2.1(5)
O(1)-C(7)-C(8)-C(9)	177.5(3)
C(7)-C(8)-C(9)-C(10)	-1.4(5)
C(8)-C(9)-C(10)-C(11)	0.7(5)
C(9)-C(10)-C(11)-C(12)	-0.5(5)

C(10)-C(11)-C(12)-C(7)	1.1(5)
C(10)-C(11)-C(12)-C(13)	177.3(3)
C(8)-C(7)-C(12)-C(11)	-1.9(5)
O(1)-C(7)-C(12)-C(11)	-177.4(3)
C(8)-C(7)-C(12)-C(13)	176.5(3)
O(1)-C(7)-C(12)-C(13)	1.0(4)
C(14)-N-C(13)-C(12)	49.8(4)
S-N-C(13)-C(12)	-99.9(3)
C(11)-C(12)-C(13)-N	-114.0(3)
C(7)-C(12)-C(13)-N	67.6(4)
C(13)-N-C(14)-C(15)	131.4(3)
S-N-C(14)-C(15)	-77.7(3)
C(13)-N-C(14)-C(16)	62.0(4)
S-N-C(14)-C(16)	-147.2(3)
N-C(14)-C(15)-C(16)	-106.3(3)
N-C(14)-C(16)-C(15)	110.5(3)

Table 8. Observed and calculated structure factors for $C_{16}H_{14}BrNO_3S$
Page 1
h k l 10Fo 10Fc 10s h k l 10Fo 10Fc 10s h k l 10Fo 10Fc 10s h k l 10Fo 10Fc 10s h k l 10Fo 10Fc 10s

2 0 0 1126 1097 20 -10 1 1 185 190 4 -9 5 1 140 125 2 8 1 2 80 89 3 9 5 2 25 16 3
4 0 0 735 770 10 -9 1 1 93 94 3 -8 5 1 65 62 3 9 1 2 32 44 6 -8 6 2 91 91 2
8 0 0 263 277 4 -8 1 1 295 299 3 -7 5 1 38 30 2 10 1 2 83 73 3 -7 6 2 323 299 3
10 0 0 646 653 10 -7 1 1 158 166 4 -6 5 1 523 545 4 11 1 2 38 44 5 -6 6 2 105 117 2
3 1 0 695 727 3 -6 1 1 185 203 4 -5 5 1 528 519 4 -11 2 2 90 83 2 -5 6 2 253 255 2
4 1 0 859 847 12 -5 1 1 248 255 6 -4 5 1 570 570 4 -10 2 2 20 24 8 -4 6 2 254 261 2
5 1 0 679 719 10 -4 1 1 371 389 5 -3 5 1 279 297 2 -9 2 2 184 180 3 -3 6 2 16 13 6
6 1 0 77 96 3 -3 1 1 375 358 2 -2 5 1 304 298 3 -8 2 2 217 222 2 -2 6 2 0 6 1
7 1 0 604 632 11 -2 1 1 1098 1108 6 -1 5 1 85 68 4 -7 2 2 491 508 5 -1 6 2 221 242 2
8 1 0 314 318 4 -1 1 1 1032 1020 6 0 5 1 552 550 6 -6 2 2 295 287 5 0 6 2 281 285 2
9 1 0 159 148 3 0 1 1 284 274 1 1 5 1 189 189 2 -5 2 2 18 10 8 1 6 2 199 211 2
10 1 0 140 137 3 1 1 1 106 106 1 2 5 1 555 554 6 -4 2 2 163 153 2 2 6 2 237 239 2
0 2 0 562 503 6 3 1 1 44 42 1 3 5 1 180 174 2 -3 2 2 636 632 6 3 6 2 345 357 2
1 2 0 42 28 1 4 1 1 182 179 2 4 5 1 150 150 2 -2 2 2 654 679 3 4 6 2 275 284 2
2 2 0 24 15 2 5 1 1 627 607 8 5 5 1 194 195 1 -1 2 2 920 905 5 5 6 2 257 252 2
3 2 0 1653 1635 17 6 1 1 169 197 5 6 5 1 461 474 4 0 2 2 563 584 3 6 6 2 124 125 2
4 2 0 284 288 4 7 1 1 88 95 10 7 5 1 293 287 3 1 2 2 569 598 4 7 6 2 45 38 3
5 2 0 283 278 3 8 1 1 452 463 5 8 5 1 141 133 3 2 2 2 186 173 2 8 6 2 85 90 2
6 2 0 187 214 2 9 1 1 378 375 5 9 5 1 82 64 2 3 2 2 454 491 4 -7 7 2 54 47 2
7 2 0 702 708 7 10 1 1 67 72 4 -8 6 1 312 291 4 4 2 2 41 9 5 -6 7 2 345 325 6
8 2 0 127 130 2 11 1 1 183 174 4 -7 6 1 21 16 4 5 2 2 604 600

6 -5 7 2 16 16 5
9 2 0 524 510 6 -11 2 1 32 25 4 -6 6 1 114 115 1 6 2 2 31 5
6 -4 7 2 11 10 10
10 2 0 95 92 2 -10 2 1 28 35 7 -5 6 1 273 283 2 7 2 2 104 108
2 -3 7 2 68 67 2
11 2 0 39 38 3 -9 2 1 479 486 5 -4 6 1 476 497 3 8 2 2 232 221
2 -2 7 2 245 247 5
1 3 0 20 18 3 -8 2 1 57 57 2 -3 6 1 153 158 1 9 2 2 234 233
2 -1 7 2 116 122 2
2 3 0 1006 1013 10 -7 2 1 49 44 3 -2 6 1 571 598 4 10 2 2 2 4
1 0 7 2 333 333 4
3 3 0 211 218 2 -6 2 1 236 251 5 -1 6 1 223 224 2 11 2 2 116
113 5 1 7 2 97 91 2
4 3 0 1310 1253 10 -5 2 1 339 347 4 0 6 1 22 15 4 -11 3 2 108
95 3 2 7 2 30 31 3
5 3 0 149 139 1 -4 2 1 16 18 6 1 6 1 237 243 2 -10 3 2 15 13
5 3 7 2 35 38 3
6 3 0 163 164 2 -3 2 1 473 484 4 2 6 1 555 565 6 -9 3 2 129 119
1 4 7 2 497 484 4
7 3 0 132 147 1 -2 2 1 1468 1471 9 3 6 1 221 222 2 -8 3 2 359
365 3 5 7 2 42 49 2
8 3 0 516 523 3 -1 2 1 804 818 5 4 6 1 377 378 2 -7 3 2 84 88
3 6 7 2 206 189 4
9 3 0 205 209 2 0 2 1 1569 1530 11 5 6 1 127 126 1 -6 3 2 140
170 2 -4 8 2 132 117 3
10 3 0 62 57 3 1 2 1 1379 1311 9 6 6 1 90 96 2 -5 3 2 551 528
5 -3 8 2 35 30 3
11 3 0 29 9 5 2 2 1 22 31 2 7 6 1 182 189 4 -4 3 2 95 76 1
-2 8 2 39 46 4
0 4 0 321 333 6 3 2 1 124 136 2 8 6 1 182 165 3 -3 3 2 638 629
5 0 8 2 76 68 3
1 4 0 193 198 2 4 2 1 165 184 2 -7 7 1 250 239 4 -2 3 2 426 423
3 1 8 2 224 216 5
2 4 0 281 282 3 5 2 1 52 64 3 -6 7 1 79 71 2 -1 3 2 58 49 3
2 8 2 308 303 5
3 4 0 594 582 4 6 2 1 338 338 4 -5 7 1 58 58 2 0 3 2 600 627
6 3 8 2 137 125 4
4 4 0 40 29 2 7 2 1 139 151 2 -4 7 1 102 99 1 1 3 2 273 284
3 4 8 2 187 181 4
5 4 0 312 298 2 8 2 1 291 291 3 -3 7 1 303 311 3 2 3 2 123 139
1 -11 0 3 159 157 4
6 4 0 132 131 1 9 2 1 292 297 3 -2 7 1 108 114 1 3 3 2 49 20
3 -9 0 3 799 807 11
7 4 0 187 198 1 10 2 1 350 348 3 -1 7 1 349 359 3 4 3 2 434
448 3 -7 0 3 221 238 6
8 4 0 69 78 3 11 2 1 73 69 4 0 7 1 194 208 2 5 3 2 156 144

2 -5 0 3 1016 983 16
9 4 0 232 247 2 -11 3 1 139 135 4 1 7 1 326 324 3 6 3 2 258 276 1 -3 0 3 1381 1353 9
10 4 0 58 68 2 -10 3 1 127 107 2 2 7 1 117 115 2 7 3 2 546 524 3 -1 0 3 110 125 2
1 5 0 252 258 3 -9 3 1 163 164 3 3 7 1 432 437 3 8 3 2 79 78 1 1 0 3 708 687 5
2 5 0 216 202 3 -8 3 1 191 198 2 4 7 1 210 218 2 9 3 2 194 184 1 3 0 3 998 1014 8
3 5 0 190 190 2 -7 3 1 375 393 2 5 7 1 268 260 4 10 3 2 162 161 4 7 0 3 875 904 15
4 5 0 256 244 2 -6 3 1 210 208 1 6 7 1 125 125 2 -10 4 2 218 208 4 9 0 3 337 352 5
5 5 0 463 480 3 -5 3 1 445 449 3 7 7 1 41 34 2 -9 4 2 67 73 1 11 0 3 171 152 4
6 5 0 89 114 3 -4 3 1 537 509 6 -4 8 1 167 145 3 -8 4 2 47 48 2 -11 1 3 73 65 4
7 5 0 245 247 3 -3 3 1 386 385 3 -3 8 1 55 52 2 -7 4 2 22 32 4 -10 1 3 211 219 5
8 5 0 170 184 2 -2 3 1 444 432 4 -2 8 1 208 183 4 -6 4 2 91 74 2 -9 1 3 32 21 7
9 5 0 139 145 3 -1 3 1 834 833 7 -1 8 1 103 103 4 -5 4 2 243 214 4 -8 1 3 469 486 6
0 6 0 453 459 5 0 3 1 513 557 4 0 8 1 59 52 3 -4 4 2 593 587 4 -7 1 3 433 448 6
1 6 0 36 29 2 1 3 1 440 461 5 1 8 1 115 119 3 -3 4 2 33 17 2 -6 1 3 174 158 4
2 6 0 94 105 1 2 3 1 330 335 4 2 8 1 292 278 5 -2 4 2 519 513 4 -5 1 3 828 798 11
3 6 0 131 144 3 3 3 1 648 664 5 3 8 1 131 128 3 -1 4 2 191 188 2 -4 1 3 917 900 11
4 6 0 298 307 2 4 3 1 33 25 3 4 8 1 142 122 2 0 4 2 698 704 5 -3 1 3 117 109 1
5 6 0 80 78 4 5 3 1 477 491 3 -10 0 2 99 96 4 1 4 2 123 104 2 -2 1 3 722 694 3
6 6 0 343 350 3 6 3 1 198 193 1 -8 0 2 14 15 7 2 4 2 359 386 2 -1 1 3 300 279 2
7 6 0 67 74 2 7 3 1 8 14 7 -4 0 2 1154 1124 11 3 4 2 206 210 2 0 1 3 861 812 4
8 6 0 54 65 2 8 3 1 44 55 2 -2 0 2 227 250 2 4 4 2 176 193 2 1 1 3 553 538 2
1 7 0 182 171 2 9 3 1 186 182 2 0 0 2 176 183 1 5 4 2 80 54 2 2 1 3 1368 1376 8
2 7 0 25 19 3 10 3 1 73 70 2 2 0 2 711 698 4 6 4 2 407 406 2 3 1 3 668 675 4
3 7 0 41 39 3 11 3 1 166 174 4 4 0 2 300 310 5 7 4 2 17 26

3 4 1 3 446 435 4
4 7 0 35 42 3 -10 4 1 6 7 5 8 0 2 107 118 7 8 4 2 369 364 2
5 1 3 548 560 9
5 7 0 148 147 2 -9 4 1 306 298 2 10 0 2 221 241 5 9 4 2 84 86
3 6 1 3 573 575 5
6 7 0 58 69 2 -8 4 1 48 58 2 -11 1 2 99 96 11 10 4 2 28 27 3
7 1 3 169 158 2
7 7 0 72 74 2 -7 4 1 223 224 2 -10 1 2 0 15 1 -9 5 2 119 103
2 8 1 3 443 476 4
0 8 0 41 43 5 -6 4 1 471 475 3 -9 1 2 101 103 8 -8 5 2 43 58
2 9 1 3 35 27 6
1 8 0 53 41 5 -5 4 1 757 754 5 -8 1 2 382 396 4 -7 5 2 217 224
2 10 1 3 45 36 4
2 8 0 91 89 2 -4 4 1 391 365 3 -7 1 2 187 186 3 -6 5 2 213 202
3 11 1 3 114 103 3
3 8 0 216 203 8 -3 4 1 238 246 2 -6 1 2 53 70 2 -5 5 2 29 28
3 -11 2 3 129 137 2
4 8 0 29 32 3 -2 4 1 423 400 4 -5 1 2 864 861 14 -4 5 2 431 409
3 -10 2 3 33 29 4
-11 0 1 19 19 16 -1 4 1 585 580 5 -4 1 2 366 351 5 -3 5 2 617
618 4 -9 2 3 124 139 3
-9 0 1 459 462 8 0 4 1 138 134 1 -3 1 2 265 294 2 -2 5 2 119
124 2 -8 2 3 152 151 2
-5 0 1 185 206 5 1 4 1 743 754 6 -2 1 2 914 919 5 -1 5 2 94 92
2 -7 2 3 199 208 2
-3 0 1 50 59 1 2 4 1 28 22 5 -1 1 2 207 180 2 0 5 2 476 483
5 -6 2 3 751 751 7
-1 0 1 274 293 1 3 4 1 333 334 3 0 1 2 36 41 1 1 5 2 494 488
7 -5 2 3 155 140 3
1 0 1 210 179 2 4 4 1 557 554 4 1 1 2 735 743 4 2 5 2 137 134
2 -4 2 3 133 132 2
3 0 1 872 826 12 5 4 1 580 572 4 2 1 2 230 229 1 3 5 2 386 398
3 -3 2 3 86 102 2
5 0 1 682 657 12 6 4 1 377 372 2 3 1 2 426 402 2 4 5 2 203 189
2 -2 2 3 835 862 5
7 0 1 451 483 11 7 4 1 428 429 3 4 1 2 490 481 4 5 5 2 102 102
1 -1 2 3 335 345 2
9 0 1 292 298 4 8 4 1 75 79 2 5 1 2 206 234 6 6 5 2 171 166
2 0 2 3 1491 1511 9
11 0 1 132 120 4 9 4 1 0 9 1 6 1 2 106 105 2 7 5 2 363 370
4 1 2 3 91 84 1
-11 1 1 105 101 4 10 4 1 181 189 6 7 1 2 219 246 3 8 5 2 7 10
6 2 2 3 352 361 3

Table 8. Observed and calculated structure factors for $C_{16}H_{14}BrNO_3S$
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h k l 10Fo 10Fc 10s h k l 10Fo 10Fc 10s h k l 10Fo 10Fc 10s h k l 10Fo 10Fc 10s h k l 10Fo 10Fc 10s

3 2 3 255 255 3 -6 7 3 0 16 1 -1 3 4 235 225 2 3 8 4 37 27 2 -1 4 5 483 489 4
4 2 3 1032 1011 15 -5 7 3 99 93 2 0 3 4 568 560 5 4 8 4 48 53 2 0 4 5 42 31 2
5 2 3 91 98 2 -4 7 3 6 6 5 1 3 4 204 214 3 -11 0 5 90 94 4 1 4 5 172 161 3
6 2 3 558 562 4 -3 7 3 11 5 10 2 3 4 855 822 6 -9 0 5 96 104 5 2 4 5 157 158 2
7 2 3 181 201 2 -2 7 3 128 130 2 3 3 4 366 349 2 -7 0 5 307 322 9 3 4 5 510 513 3
8 2 3 109 106 3 -1 7 3 144 155 2 4 3 4 35 8 2 -5 0 5 137 130 6 4 4 5 217 230 1
9 2 3 124 142 3 0 7 3 126 125 2 5 3 4 63 69 1 -3 0 5 879 850 10 5 4 5 394 410 2
10 2 3 230 207 2 1 7 3 269 278 2 6 3 4 294 316 2 -1 0 5 455 477 3 6 4 5 113 130 2
11 2 3 15 11 15 2 7 3 49 44 2 7 3 4 107 108 1 1 0 5 710 730 4 7 4 5 41 33 2
-11 3 3 213 207 5 3 7 3 52 56 2 8 3 4 150 153 2 3 0 5 473 494 4 8 4 5 78 84 2
-10 3 3 24 37 3 4 7 3 27 30 3 9 3 4 89 72 1 5 0 5 750 715 17 9 4 5 212 188 9
-9 3 3 203 207 2 5 7 3 107 88 3 10 3 4 127 126 2 7 0 5 347 348 5 -9 5 5 239 229 4
-8 3 3 152 163 1 6 7 3 29 16 3 -10 4 4 178 173 5 9 0 5 297 300 5 -8 5 5 211 205 3
-7 3 3 491 503 4 -4 8 3 54 57 2 -9 4 4 106 104 1 -11 1 5 142 136 8 -7 5 5 16 25 5
-6 3 3 144 151 1 -3 8 3 26 29 3 -8 4 4 332 327 3 -10 1 5 193 196 5 -6 5 5 360 363 2
-5 3 3 583 594 4 -2 8 3 169 153 3 -7 4 4 64 78 2 -9 1 5 47 55 3 -5 5 5 284 274 3
-4 3 3 195 187 2 -1 8 3 0 8 1 -6 4 4 74 76 1 -8 1 5 226 236 4 -4 5 5 175 185 2
-3 3 3 355 348 2 0 8 3 159 152 4 -5 4 4 431 421 3 -7 1 5 65 69 2 -3 5 5 168 171 2
-2 3 3 535 524 4 1 8 3 47 44 3 -4 4 4 666 664 5 -6 1 5 78 80 2 -2 5 5 597 591 7
-1 3 3 768 808 7 2 8 3 148 145 3 -3 4 4 134 138 2 -5 1 5 217

246 3 -1 5 5 59 61 2
0 3 3 340 343 3 3 8 3 162 157 3 -2 4 4 479 504 4 -4 1 5 359 354 3 0 5 5 344 338 3
1 3 3 55 56 2 4 8 3 62 48 2 -1 4 4 662 634 5 -3 1 5 598 590 4 1 5 5 366 378 3
2 3 3 52 50 2 -10 0 4 118 119 4 0 4 4 64 62 2 -2 1 5 563 528 2 2 5 5 70 54 2
3 3 3 471 471 4 -8 0 4 33 40 4 1 4 4 662 639 5 -1 1 5 833 809 3 3 5 5 175 189 2
4 3 3 83 75 1 -6 0 4 477 456 7 2 4 4 964 955 7 0 1 5 670 666 3 4 5 5 665 682 4
5 3 3 714 743 4 -4 0 4 368 339 4 3 4 4 119 97 2 1 1 5 217 225 1 5 5 5 38 31 2
6 3 3 180 194 1 -2 0 4 1274 1311 10 4 4 4 187 189 1 2 1 5 94 118 1 6 5 5 99 118 2
7 3 3 88 94 1 2 0 4 591 568 4 5 4 4 200 228 2 3 1 5 177 191 1 7 5 5 244 225 2
8 3 3 82 70 1 4 0 4 1105 1057 12 6 4 4 224 229 2 4 1 5 208 220 3 8 5 5 189 178 3
9 3 3 264 252 2 6 0 4 674 654 15 7 4 4 241 259 2 5 1 5 364 384 7 -8 6 5 76 75 2
10 3 3 60 46 2 8 0 4 57 58 4 8 4 4 217 202 2 6 1 5 61 50 3 -7 6 5 168 162 2
-10 4 3 224 223 3 10 0 4 358 357 10 9 4 4 86 91 2 7 1 5 28 24 3 -6 6 5 152 149 1
-9 4 3 211 195 2 -11 1 4 45 42 6 -9 5 4 286 276 4 8 1 5 218 218 2 -5 6 5 73 73 1
-8 4 3 66 72 2 -10 1 4 122 117 4 -8 5 4 119 108 2 9 1 5 126 123 3 -4 6 5 356 364 3
-7 4 3 14 5 6 -9 1 4 158 163 4 -7 5 4 153 153 3 10 1 5 22 13 9 -3 6 5 321 317 3
-6 4 3 286 307 2 -8 1 4 241 243 3 -6 5 4 77 74 2 -11 2 5 25 33 4 -2 6 5 245 257 2
-5 4 3 51 33 4 -7 1 4 613 653 12 -5 5 4 232 237 2 -10 2 5 278 273 3 -1 6 5 326 320 3
-4 4 3 45 61 3 -6 1 4 268 268 4 -4 5 4 140 127 2 -9 2 5 72 64 3 0 6 5 349 363 3
-3 4 3 489 481 3 -5 1 4 230 231 5 -3 5 4 322 338 3 -8 2 5 126 124 3 1 6 5 141 140 2
-2 4 3 508 498 4 -4 1 4 663 658 6 -2 5 4 334 330 4 -7 2 5 292 265 4 2 6 5 417 432 3
-1 4 3 199 189 2 -3 1 4 712 693 5 -1 5 4 376 367 4 -6 2 5 362 386 3 3 6 5 199 209 1
0 4 3 666 650 5 -2 1 4 77 82 1 0 5 4 25 40 4 -5 2 5 157 139 2 4 6 5 112 120 1
1 4 3 55 70 2 -1 1 4 604 607 3 1 5 4 627 618 5 -4 2 5 511 506

5 5 6 5 267 277 2
2 4 3 260 260 2 0 1 4 1448 1380 14 2 5 4 245 227 2 -3 2 5 215 209 3 6 6 5 239 227 2
3 4 3 247 261 2 1 1 4 145 144 1 3 5 4 389 414 3 -2 2 5 18 8 3 7 6 5 28 18 3
4 4 3 218 230 1 2 1 4 576 577 2 4 5 4 313 307 2 -1 2 5 115 140 1 -7 7 5 76 63 2
5 4 3 210 218 1 3 1 4 1240 1208 8 5 5 4 81 75 3 0 2 5 964 1000 5 -6 7 5 25 27 3
6 4 3 207 222 1 4 1 4 287 280 2 6 5 4 79 96 2 1 2 5 308 271 5 -5 7 5 315 296 4
7 4 3 100 92 1 5 1 4 665 644 9 7 5 4 191 191 2 2 2 5 555 532 4 -4 7 5 89 85 2
8 4 3 170 162 2 6 1 4 542 539 5 8 5 4 176 186 2 3 2 5 286 264 3 -3 7 5 324 331 3
9 4 3 278 272 3 7 1 4 80 82 2 9 5 4 176 155 4 4 2 5 387 388 4 -2 7 5 129 148 2
-9 5 3 41 41 3 8 1 4 320 331 3 -8 6 4 93 91 2 5 2 5 26 11 3 -1 7 5 102 103 2
-8 5 3 209 188 2 9 1 4 175 171 2 -7 6 4 210 194 2 6 2 5 101 119 1 0 7 5 127 139 2
-7 5 3 43 49 2 10 1 4 152 144 3 -6 6 4 36 46 2 7 2 5 36 33 2 1 7 5 450 458 7
-6 5 3 176 180 1 11 1 4 198 199 4 -5 6 4 164 166 2 8 2 5 99 96 3 2 7 5 103 100 2
-5 5 3 102 99 1 -11 2 4 191 182 4 -4 6 4 130 131 2 9 2 5 20 11 4 3 7 5 83 75 3
-4 5 3 325 329 3 -10 2 4 118 113 3 -3 6 4 181 187 4 10 2 5 18 11 4 4 7 5 64 60 2
-3 5 3 55 29 2 -9 2 4 331 327 3 -2 6 4 257 267 2 -11 3 5 40 64 10 5 7 5 72 60 2
-2 5 3 388 386 6 -8 2 4 116 126 2 -1 6 4 452 474 3 -10 3 5 26 23 4 6 7 5 27 15 3
-1 5 3 189 169 3 -7 2 4 243 255 3 0 6 4 243 247 2 -9 3 5 189 196 2 -4 8 5 312 279 4
0 5 3 189 192 2 -6 2 4 149 160 2 1 6 4 25 9 3 -8 3 5 345 342 2 -3 8 5 164 156 3
1 5 3 78 67 4 -5 2 4 577 571 5 2 6 4 125 128 2 -7 3 5 65 66 1 -2 8 5 96 93 2
2 5 3 561 563 4 -4 2 4 569 513 6 3 6 4 283 288 3 -6 3 5 142 135 2 -1 8 5 153 146 4
3 5 3 139 152 2 -3 2 4 584 576 5 4 6 4 18 12 4 -5 3 5 137 163 1 1 8 5 7 9 7
4 5 3 314 327 2 -2 2 4 579 577 4 5 6 4 362 357 2 -4 3 5 139 136 1 2 8 5 246 229 7
5 5 3 57 50 2 -1 2 4 550 535 2 6 6 4 29 32 3 -3 3 5 434 415

3 3 8 5 101 96 2
6 5 3 114 127 1 0 2 4 545 547 2 7 6 4 32 16 3 -2 3 5 611 608
5 -10 0 6 0 5 1
7 5 3 91 86 2 1 2 4 317 332 2 8 6 4 106 92 3 -1 3 5 191 165
2 -8 0 6 432 451 8
8 5 3 225 215 3 2 2 4 34 35 2 -7 7 4 77 68 2 0 3 5 431 436
3 -6 0 6 448 484 6
9 5 3 82 77 2 3 2 4 404 383 3 -6 7 4 231 221 5 1 3 5 1185 1161
8 -4 0 6 198 201 8
-8 6 3 22 28 4 4 2 4 457 438 4 -5 7 4 29 22 3 2 3 5 290 263
2 -2 0 6 1713 1681 15
-7 6 3 85 95 2 5 2 4 625 622 5 -4 7 4 128 124 3 3 3 5 136 119
1 2 0 6 618 632 6
-6 6 3 11 2 10 6 2 4 44 46 1 -3 7 4 69 63 2 4 3 5 275 272 2
4 0 6 641 678 11
-5 6 3 139 138 1 7 2 4 550 565 3 -2 7 4 366 363 5 5 3 5 99 120
1 6 0 6 207 226 12
-4 6 3 27 28 3 8 2 4 141 148 2 -1 7 4 177 176 2 6 3 5 63 62
2 8 0 6 284 282 4
-3 6 3 249 250 3 9 2 4 10 17 10 0 7 4 264 268 4 7 3 5 323 333
2 10 0 6 258 241 8
-2 6 3 18 17 4 10 2 4 90 85 2 1 7 4 46 58 3 8 3 5 34 21 2
-11 1 6 140 138 4
-1 6 3 94 102 2 11 2 4 104 84 3 2 7 4 27 13 3 9 3 5 159 159
1 -10 1 6 76 69 6
0 6 3 183 201 2 -11 3 4 59 58 6 3 7 4 179 173 2 10 3 5 104 90
4 -9 1 6 454 459 4
1 6 3 388 391 3 -10 3 4 89 74 2 4 7 4 196 190 2 -10 4 5 70 59
2 -8 1 6 471 485 4
2 6 3 299 308 2 -9 3 4 222 210 2 5 7 4 10 5 9 -9 4 5 69 60 2
-7 1 6 455 481 4
3 6 3 152 155 1 -8 3 4 28 27 2 6 7 4 167 145 3 -8 4 5 13 21
8 -6 1 6 153 145 2
4 6 3 212 219 2 -7 3 4 217 214 2 -4 8 4 171 157 3 -7 4 5 383
384 2 -5 1 6 319 333 2
5 6 3 18 19 5 -6 3 4 416 421 3 -3 8 4 11 6 11 -6 4 5 94 104
2 -4 1 6 514 510 5
6 6 3 138 131 2 -5 3 4 52 64 2 -2 8 4 58 59 4 -5 4 5 27 25 3
-3 1 6 739 716 5
7 6 3 137 121 4 -4 3 4 492 471 3 0 8 4 60 68 3 -4 4 5 140 120
2 -2 1 6 679 686 3
8 6 3 110 104 2 -3 3 4 248 193 4 1 8 4 16 17 7 -3 4 5 385 395
3 -1 1 6 1337 1317 6
-7 7 3 11 27 8 -2 3 4 336 317 3 2 8 4 29 34 3 -2 4 5 176 151
2 0 1 6 99 99 1

Table 8. Observed and calculated structure factors for $C_{16}H_{14}BrNO_3S$
Page 3

h k l 10Fo 10Fc 10s h k l 10Fo 10Fc 10s h k l 10Fo 10Fc 10s h k l 10Fo 10Fc 10s h k l 10Fo 10Fc 10s

1 1 6 100 85 1 6 5 6 122 137 2 4 2 7 239 246 2 0 7 7 46 56 3 -6 4 8 350 354 2
2 1 6 1032 1005 8 7 5 6 77 71 2 5 2 7 422 438 3 1 7 7 414 408 5 -5 4 8 200 199 2
3 1 6 598 648 4 8 5 6 33 48 3 6 2 7 57 56 2 2 7 7 71 78 2 -4 4 8 384 395 3
4 1 6 393 372 5 -8 6 6 99 88 2 7 2 7 60 69 1 3 7 7 96 81 2 -3 4 8 92 75 2
5 1 6 348 388 3 -7 6 6 26 19 3 8 2 7 361 346 2 4 7 7 15 3 5 -2 4 8 201 189 2
6 1 6 231 232 3 -6 6 6 112 113 3 9 2 7 45 46 1 5 7 7 137 136 2 -1 4 8 260 240 2
7 1 6 78 82 2 -5 6 6 68 60 4 10 2 7 88 100 6 -3 8 7 52 52 2 0 4 8 461 466 3
8 1 6 197 201 2 -4 6 6 77 78 2 -11 3 7 61 60 3 -2 8 7 56 44 4 1 4 8 211 217 3
9 1 6 299 295 3 -3 6 6 81 85 2 -10 3 7 154 161 1 0 8 7 147 149 8 2 4 8 366 372 5
10 1 6 8 7 8 -2 6 6 187 193 2 -9 3 7 190 189 2 1 8 7 49 48 3 3 4 8 68 90 2
-11 2 6 166 158 5 -1 6 6 22 28 3 -8 3 7 250 254 2 2 8 7 95 83 2 4 4 8 385 375 3
-10 2 6 81 88 2 0 6 6 201 202 2 -7 3 7 407 417 2 -10 0 8 11 5 10 5 4 8 113 122 2
-9 2 6 325 322 3 1 6 6 73 70 2 -6 3 7 206 200 2 -8 0 8 589 595 6 6 4 8 284 285 2
-8 2 6 316 332 3 2 6 6 163 171 2 -5 3 7 103 99 1 -6 0 8 655 658 9 7 4 8 17 8 4
-7 2 6 39 37 3 3 6 6 91 95 3 -4 3 7 271 266 2 -4 0 8 851 814 7 8 4 8 96 78 4
-6 2 6 153 170 1 4 6 6 253 257 2 -3 3 7 744 727 5 -2 0 8 1354 1255 15 9 4 8 16 18 8
-5 2 6 981 948 7 5 6 6 104 109 1 -2 3 7 448 444 3 0 0 8 1169 1132 11 -9 5 8 11 14 10
-4 2 6 33 38 2 6 6 6 136 140 3 -1 3 7 78 88 2 2 0 8 186 174 4 -8 5 8 120 114 2
-3 2 6 448 453 4 7 6 6 71 49 2 0 3 7 331 347 2 4 0 8 335 328 8 -7 5 8 123 125 2
-2 2 6 677 672 5 -7 7 6 12 7 9 1 3 7 536 548 4 6 0 8 252 265

2 -6 5 8 154 160 2
-1 2 6 254 281 2 -6 7 6 94 84 2 2 3 7 209 214 3 8 0 8 104 103
4 -5 5 8 449 468 3
0 2 6 581 573 4 -5 7 6 116 117 2 3 3 7 423 439 3 -11 1 8 72 67
12 -4 5 8 60 61 2
1 2 6 468 499 4 -4 7 6 101 85 2 4 3 7 251 243 1 -10 1 8 220 216
2 -3 5 8 52 46 2
2 2 6 372 374 3 -3 7 6 63 58 2 5 3 7 147 153 1 -9 1 8 131 129
2 -2 5 8 287 304 2
3 2 6 792 784 6 -2 7 6 14 9 9 6 3 7 38 53 1 -8 1 8 167 174 2
-1 5 8 544 554 5
4 2 6 136 179 2 -1 7 6 177 168 2 7 3 7 308 310 2 -7 1 8 132 135
2 0 5 8 95 111 2
5 2 6 328 329 3 0 7 6 12 7 12 8 3 7 110 112 1 -6 1 8 121 119
1 1 5 8 577 600 4
6 2 6 284 293 2 1 7 6 92 88 2 9 3 7 230 226 3 -5 1 8 321 319
2 2 5 8 259 258 4
7 2 6 476 476 3 2 7 6 179 171 7 -10 4 7 9 17 8 -4 1 8 404 381
2 3 5 8 156 149 2
8 2 6 66 61 1 3 7 6 26 29 3 -9 4 7 86 89 2 -3 1 8 297 270 3
4 5 8 336 333 2
9 2 6 136 140 4 4 7 6 178 166 3 -8 4 7 105 104 2 -2 1 8 423 413
3 5 5 8 428 441 3
10 2 6 92 96 3 5 7 6 41 43 2 -7 4 7 513 524 3 -1 1 8 709 676
4 6 5 8 10 17 10
-11 3 6 76 67 3 -4 8 6 143 135 3 -6 4 7 177 181 2 0 1 8 162 168
1 7 5 8 303 291 6
-10 3 6 226 222 3 -3 8 6 52 34 2 -5 4 7 240 252 2 1 1 8 254 236
2 8 5 8 138 130 4
-9 3 6 108 120 1 -2 8 6 36 29 5 -4 4 7 245 243 2 2 1 8 348 344
3 -8 6 8 82 79 2
-8 3 6 69 74 2 -1 8 6 88 77 4 -3 4 7 384 388 3 3 1 8 79 61 2
-7 6 8 227 226 3
-7 3 6 45 46 2 0 8 6 19 18 8 -2 4 7 355 346 3 4 1 8 26 20 3
-6 6 8 273 261 4
-6 3 6 596 578 4 1 8 6 49 40 4 -1 4 7 537 548 4 5 1 8 171 186
1 -5 6 8 13 2 7
-5 3 6 275 256 2 2 8 6 36 42 3 0 4 7 92 91 1 6 1 8 51 46 4
-4 6 8 242 235 3
-4 3 6 727 723 5 3 8 6 85 73 2 1 4 7 47 23 3 7 1 8 75 76 2
-3 6 8 248 257 2
-3 3 6 24 14 3 -11 0 7 189 188 4 2 4 7 236 233 2 8 1 8 51 44
1 -2 6 8 259 261 2
-2 3 6 197 189 2 -9 0 7 381 390 6 3 4 7 339 330 2 9 1 8 89 83
2 -1 6 8 203 208 2
-1 3 6 33 48 3 -7 0 7 531 567 6 4 4 7 207 212 1 -11 2 8 30 41

10 0 6 8 251 252 2
0 3 6 807 798 6 -5 0 7 303 324 3 5 4 7 562 561 3 -10 2 8 196 197 2 1 6 8 304 315 4
1 3 6 314 315 2 -3 0 7 263 254 4 6 4 7 111 107 2 -9 2 8 296 300 2 2 6 8 24 9 3
2 3 6 589 603 4 -1 0 7 74 64 2 7 4 7 44 50 3 -8 2 8 41 45 2 3 6 8 359 367 3
3 3 6 69 65 2 1 0 7 837 816 9 8 4 7 161 163 4 -7 2 8 287 311 2 4 6 8 219 223 2
4 3 6 183 186 1 3 0 7 223 217 5 9 4 7 102 99 3 -6 2 8 97 96 1 5 6 8 234 218 2
5 3 6 278 273 1 5 0 7 677 708 9 -9 5 7 64 58 3 -5 2 8 497 475 3 6 6 8 196 194 5
6 3 6 547 541 3 7 0 7 410 423 5 -8 5 7 228 229 4 -4 2 8 48 37 2 -6 7 8 82 74 2
7 3 6 65 57 1 9 0 7 7 25 7 -7 5 7 35 35 3 -3 2 8 359 350 2 -5 7 8 48 48 2
8 3 6 132 139 2 -11 1 7 133 134 5 -6 5 7 409 420 3 -2 2 8 16 17 4 -4 7 8 195 177 3
9 3 6 42 36 1 -10 1 7 148 149 2 -5 5 7 228 238 2 -1 2 8 247 226 2 -3 7 8 10 3 9
-10 4 6 22 16 4 -9 1 7 317 321 3 -4 5 7 17 15 4 0 2 8 419 420 3 -2 7 8 362 356 7
-9 4 6 138 143 2 -8 1 7 45 44 2 -3 5 7 22 38 5 1 2 8 504 499 3 -1 7 8 97 86 3
-8 4 6 82 69 2 -7 1 7 29 31 3 -2 5 7 372 378 4 2 2 8 73 42 4 0 7 8 33 23 3
-7 4 6 180 170 1 -6 1 7 351 363 3 -1 5 7 100 94 2 3 2 8 647 640 4 1 7 8 22 25 5
-6 4 6 83 85 1 -5 1 7 172 167 1 0 5 7 434 461 4 4 2 8 33 4 2 2 7 8 209 192 3
-5 4 6 518 508 4 -4 1 7 137 100 1 1 5 7 107 94 2 5 2 8 147 146 2 3 7 8 23 24 3
-4 4 6 24 22 3 -3 1 7 534 519 3 2 5 7 234 245 2 6 2 8 191 179 2 4 7 8 290 275 4
-3 4 6 283 287 2 -2 1 7 123 120 1 3 5 7 41 44 2 7 2 8 166 162 1 5 7 8 44 39 2
-2 4 6 303 324 3 -1 1 7 232 217 1 4 5 7 239 248 2 8 2 8 61 54 1 -3 8 8 275 250 10
-1 4 6 223 225 2 0 1 7 662 652 3 5 5 7 79 64 2 9 2 8 131 128 5 0 8 8 118 118 3
0 4 6 516 518 4 1 1 7 673 672 4 6 5 7 114 119 3 -11 3 8 175 170 3 1 8 8 176 159 6
1 4 6 45 57 2 2 1 7 440 429 3 7 5 7 49 40 3 -10 3 8 217 221 2 2 8 8 137 138 4
2 4 6 213 213 2 3 1 7 307 309 4 8 5 7 60 57 2 -9 3 8 280 279

2 -11 0 9 397 411 11
3 4 6 238 232 2 4 1 7 406 389 6 -8 6 7 78 74 2 -8 3 8 441 453
4 -9 0 9 236 245 3
4 4 6 91 89 1 5 1 7 23 24 4 -7 6 7 198 189 3 -7 3 8 54 55 2
-7 0 9 337 332 4
5 4 6 199 204 1 6 1 7 338 350 3 -6 6 7 215 217 2 -6 3 8 276 269
2 -5 0 9 915 873 8
6 4 6 233 240 2 7 1 7 328 321 2 -5 6 7 41 37 2 -5 3 8 276 274
2 -3 0 9 90 83 3
7 4 6 129 135 2 8 1 7 107 120 2 -4 6 7 487 514 4 -4 3 8 608 585
4 -1 0 9 1402 1348 24
8 4 6 7 1 7 9 1 7 144 139 3 -3 6 7 27 23 3 -3 3 8 27 7 3
1 0 9 916 913 9
9 4 6 8 7 8 10 1 7 233 224 4 -2 6 7 114 133 3 -2 3 8 626 610
4 3 0 9 104 90 12
-9 5 6 193 182 3 -11 2 7 119 124 2 -1 6 7 149 147 1 -1 3 8 207
217 1 5 0 9 879 894 8
-8 5 6 150 156 2 -10 2 7 199 193 3 0 6 7 166 169 2 0 3 8 22 18
3 7 0 9 559 561 5
-7 5 6 135 153 5 -9 2 7 183 188 2 1 6 7 145 148 2 1 3 8 178 191
1 9 0 9 154 144 11
-6 5 6 93 87 2 -8 2 7 77 77 1 2 6 7 408 430 3 2 3 8 574 576
4 -11 1 9 91 93 4
-5 5 6 32 30 3 -7 2 7 39 53 2 3 6 7 146 147 3 3 3 8 129 110
2 -10 1 9 427 422 4
-4 5 6 274 270 3 -6 2 7 32 40 2 4 6 7 109 122 5 4 3 8 250 262
2 -9 1 9 128 130 2
-3 5 6 119 126 3 -5 2 7 295 294 2 5 6 7 156 143 4 5 3 8 307 301
2 -8 1 9 25 32 3
-2 5 6 18 16 6 -4 2 7 639 609 5 6 6 7 132 129 2 6 3 8 203 209
2 -7 1 9 460 465 3
-1 5 6 244 260 2 -3 2 7 26 30 3 7 6 7 51 44 3 7 3 8 146 136
1 -6 1 9 601 584 5
0 5 6 37 32 2 -2 2 7 710 723 5 -6 7 7 36 24 2 8 3 8 187 187
1 -5 1 9 22 40 3
1 5 6 74 69 2 -1 2 7 299 291 2 -5 7 7 223 214 3 9 3 8 89 91
2 -4 1 9 700 678 4
2 5 6 319 313 3 0 2 7 336 337 3 -4 7 7 168 173 2 -10 4 8 94 87
2 -3 1 9 951 902 5
3 5 6 346 351 2 1 2 7 30 22 2 -3 7 7 177 168 3 -9 4 8 109 115
3 -2 1 9 48 70 4
4 5 6 134 143 1 2 2 7 492 507 3 -2 7 7 16 23 7 -8 4 8 33 35
3 -1 1 9 675 653 6
5 5 6 29 32 3 3 2 7 227 210 2 -1 7 7 116 104 3 -7 4 8 205 190
3 0 1 9 1560 1519 14

Table 8. Observed and calculated structure factors for C16H14BrNO3S
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h k l 10Fo 10Fc 10s h k l 10Fo 10Fc 10s h k l 10Fo 10Fc 10s h k l 10Fo 10Fc 10s h k l 10Fo 10Fc 10s

1 1 9 29 24 3 -7 6 9 159 156 2 1 3 10 64 62 2 -3 1 11 55 43 2 -5 6 11 80 79 2
2 1 9 566 546 5 -6 6 9 116 114 2 2 3 10 251 240 2 -2 1 11 178 166 1 -4 6 11 288 301 3
3 1 9 831 818 9 -5 6 9 287 292 4 3 3 10 112 104 1 -1 1 11 507 494 4 -3 6 11 177 170 3
4 1 9 308 308 2 -4 6 9 60 54 2 4 3 10 418 439 3 0 1 11 88 97 2 -2 6 11 208 209 2
5 1 9 422 433 3 -3 6 9 205 204 2 5 3 10 190 195 4 1 1 11 397 374 4 -1 6 11 90 88 2
6 1 9 691 701 4 -2 6 9 64 73 3 6 3 10 570 587 4 2 1 11 200 206 2 0 6 11 414 425 5
7 1 9 287 280 2 -1 6 9 130 137 2 7 3 10 156 151 2 3 1 11 357 337 3 1 6 11 272 269 3
8 1 9 213 225 3 0 6 9 115 121 2 8 3 10 125 108 2 4 1 11 64 73 2 2 6 11 230 239 5
9 1 9 328 315 5 1 6 9 199 200 2 -10 4 10 187 175 2 5 1 11 206 206 1 3 6 11 232 232 4
-11 2 9 234 244 4 2 6 9 119 122 2 -9 4 10 45 51 3 6 1 11 240 231 2 4 6 11 163 161 2
-10 2 9 122 109 2 3 6 9 100 111 1 -8 4 10 30 39 3 7 1 11 295 293 2 5 6 11 103 110 2
-9 2 9 162 171 2 4 6 9 77 65 2 -7 4 10 390 402 2 8 1 11 127 112 1 -5 7 11 209 197 3
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-7 2 9 398 394 2 6 6 9 101 93 3 -5 4 10 493 510 3 -10 2 11 23 17 3 -3 7 11 18 13 8
-6 2 9 412 417 3 -6 7 9 69 66 2 -4 4 10 552 567 4 -9 2 11 243 242 2 -2 7 11 39 56 5
-5 2 9 263 259 2 -5 7 9 207 200 3 -3 4 10 58 64 3 -8 2 11 348 355 4 -1 7 11 488 478 22
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-1 2 9 549 553 3 -1 7 9 223 219 10 1 4 10 272 267 3 -4 2 11 285

274 2 3 7 11 215 205 3
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1 2 9 450 439 3 1 7 9 180 183 3 3 4 10 190 198 1 -2 2 11 492 475 3 -8 0 12 444 446 4
2 2 9 914 863 7 2 7 9 233 241 3 4 4 10 148 149 2 -1 2 11 72 46 1 -6 0 12 203 206 2
3 2 9 266 266 2 3 7 9 174 169 3 5 4 10 358 381 3 0 2 11 649 648 6 -4 0 12 506 498 4
4 2 9 708 715 5 4 7 9 68 59 1 6 4 10 269 270 3 1 2 11 205 187 4 -2 0 12 945 907 8
5 2 9 123 137 1 -2 8 9 156 138 4 7 4 10 119 129 2 2 2 11 235 230 3 0 0 12 40 11 5
6 2 9 29 26 2 -10 0 10 199 191 5 8 4 10 98 83 8 3 2 11 35 31 3 2 0 12 1047 1022 11
7 2 9 202 221 1 -8 0 10 355 374 3 -9 5 10 301 291 6 4 2 11 503 496 3 4 0 12 377 387 4
8 2 9 357 343 2 -6 0 10 183 184 2 -8 5 10 57 50 2 5 2 11 140 151 1 6 0 12 102 97 4
9 2 9 58 44 2 -4 0 10 687 661 6 -7 5 10 107 106 2 6 2 11 124 123 3 8 0 12 289 271 3
-11 3 9 4 8 4 -2 0 10 1430 1366 14 -6 5 10 76 81 2 7 2 11 156 154 1 -11 1 12 133 129 2
-10 3 9 55 41 2 0 0 10 199 164 6 -5 5 10 297 306 2 8 2 11 32 41 3 -10 1 12 39 38 2
-9 3 9 364 364 3 2 0 10 1113 1076 20 -4 5 10 125 134 2 -10 3 11 164 149 2 -9 1 12 485 483 4
-8 3 9 63 68 2 4 0 10 261 270 3 -3 5 10 381 401 3 -9 3 11 46 40 3 -8 1 12 206 200 2
-7 3 9 310 333 2 6 0 10 115 119 2 -2 5 10 177 197 2 -8 3 11 130 128 1 -7 1 12 277 278 2
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-5 3 9 178 159 3 -11 1 10 19 21 6 0 5 10 59 54 3 -6 3 11 16 9 5 -5 1 12 421 412 2
-4 3 9 286 287 2 -10 1 10 22 21 3 1 5 10 525 539 4 -5 3 11 14 11 8 -4 1 12 531 510 3
-3 3 9 829 801 7 -9 1 10 438 449 4 2 5 10 294 301 4 -4 3 11 629 619 5 -3 1 12 905 880 6
-2 3 9 263 252 2 -8 1 10 74 72 3 3 5 10 351 365 2 -3 3 11 131 132 2 -2 1 12 129 141 2
-1 3 9 247 249 2 -7 1 10 189 194 2 4 5 10 19 19 4 -2 3 11 542 547 4 -1 1 12 347 326 3
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1 3 9 266 279 3 -5 1 10 407 386 3 6 5 10 139 159 3 0 3 11 139

127 4 1 1 12 473 486 4
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3 3 9 775 774 5 -3 1 10 1001 939 6 -8 6 10 140 144 4 2 3 11 197 202 2 3 1 12 640 633 4
4 3 9 178 187 1 -2 1 10 354 354 2 -7 6 10 202 186 4 3 3 11 197 200 2 4 1 12 314 305 3
5 3 9 34 41 2 -1 1 10 467 439 3 -6 6 10 94 90 2 4 3 11 182 182 2 5 1 12 131 115 3
6 3 9 25 27 2 0 1 10 341 331 3 -5 6 10 162 173 3 5 3 11 267 278 2 6 1 12 559 548 3
7 3 9 167 160 1 1 1 10 903 880 8 -4 6 10 234 236 2 6 3 11 292 296 3 7 1 12 194 180 1
8 3 9 78 62 2 2 1 10 261 226 3 -3 6 10 225 241 2 7 3 11 137 144 2 8 1 12 19 19 2
9 3 9 223 211 5 3 1 10 643 638 6 -2 6 10 66 72 2 8 3 11 220 203 4 -10 2 12 214 211 2
-10 4 9 60 56 2 4 1 10 128 122 1 -1 6 10 194 203 3 -10 4 11 37 28 3 -9 2 12 90 93 2
-9 4 9 207 209 2 5 1 10 46 37 2 0 6 10 67 57 3 -9 4 11 147 131 2 -8 2 12 384 396 4
-8 4 9 214 233 3 6 1 10 27 25 2 1 6 10 328 324 6 -8 4 11 14 4 9 -7 2 12 468 467 3
-7 4 9 146 146 1 7 1 10 351 354 2 2 6 10 392 403 3 -7 4 11 368 377 2 -6 2 12 157 149 2
-6 4 9 255 268 2 8 1 10 46 41 1 3 6 10 307 303 3 -6 4 11 126 134 3 -5 2 12 679 676 4
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-2 4 9 293 285 3 -9 2 10 23 11 4 -6 7 10 109 109 4 -2 4 11 26 28 5 -1 2 12 450 454 3
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1 4 9 478 496 4 -6 2 10 22 29 4 -3 7 10 59 53 2 1 4 11 202 215 2 2 2 12 409 417 3
2 4 9 495 504 3 -5 2 10 470 459 3 -2 7 10 291 278 22 2 4 11 108 108 1 3 2 12 25 20 4
3 4 9 246 255 2 -4 2 10 467 435 3 -1 7 10 108 115 8 3 4 11 488 506 3 4 2 12 64 75 2
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6 4 9 90 78 3 -1 2 10 836 825 5 2 7 10 252 246 3 6 4 11 55 42 4 7 2 12 176 173 3
7 4 9 255 241 3 0 2 10 251 248 2 3 7 10 10 12 9 7 4 11 338 321 5 8 2 12 98 93 3
8 4 9 201 194 5 1 2 10 329 319 3 4 7 10 231 217 3 -9 5 11 23 24 4 -10 3 12 179 174 3
-9 5 9 108 113 2 2 2 10 523 518 4 -11 0 11 77 64 9 -8 5 11 250 244 3 -9 3 12 72 76 2
-8 5 9 45 41 3 3 2 10 201 204 2 -9 0 11 208 215 5 -7 5 11 273 270 3 -8 3 12 87 80 2
-7 5 9 158 169 1 4 2 10 265 279 2 -7 0 11 38 9 5 -6 5 11 18 3 5 -7 3 12 100 99 1
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-5 5 9 56 54 3 6 2 10 45 46 1 -3 0 11 389 379 3 -4 5 11 491 509 4 -5 3 12 289 287 2
-4 5 9 176 190 3 7 2 10 96 99 3 -1 0 11 144 154 2 -3 5 11 135 132 4 -4 3 12 169 183 2
-3 5 9 240 239 7 8 2 10 166 175 2 1 0 11 589 576 8 -2 5 11 299 300 3 -3 3 12 23 19 5
-2 5 9 25 18 3 -10 3 10 115 115 2 3 0 11 548 538 7 -1 5 11 199 215 2 -2 3 12 245 250 2
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2 5 9 167 174 1 -6 3 10 661 675 4 -10 1 11 39 36 2 3 5 11 95 107 3 2 3 12 300 314 3
3 5 9 167 180 1 -5 3 10 253 260 2 -9 1 11 49 50 2 4 5 11 303 321 5 3 3 12 237 235 4
4 5 9 50 51 2 -4 3 10 205 212 2 -8 1 11 53 62 2 5 5 11 245 239 2 4 3 12 353 360 4
5 5 9 11 13 11 -3 3 10 259 244 2 -7 1 11 330 336 2 6 5 11 163 151 3 5 3 12 235 238 2
6 5 9 295 299 4 -2 3 10 854 842 6 -6 1 11 248 226 2 7 5 11 14 6 9 6 3 12 344 342 4
7 5 9 140 135 3 -1 3 10 397 387 3 -5 1 11 272 268 2 -7 6 11 96 94 2 7 3 12 21 27 4
-8 6 9 17 5 4 0 3 10 973 946 7 -4 1 11 430 410 3 -6 6 11 234 220 5 8 3 12 41 22 8

Table 8. Observed and calculated structure factors for $C_{16}H_{14}BrNO_3S$
Page 5

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-8 4 12 219 207 3 -2 2 13 115 111 2 -10 1 14 249 231 4 -2 6 14 162 149 3 0 5 15 196 194 7
-7 4 12 394 400 2 -1 2 13 395 384 3 -9 1 14 81 90 2 -1 6 14 82 79 9 1 5 15 164 166 4
-6 4 12 77 76 1 0 2 13 751 745 7 -8 1 14 253 257 2 0 6 14 199 199 4 2 5 15 75 70 3
-5 4 12 376 384 2 1 2 13 278 263 2 -7 1 14 12 16 11 1 6 14 347 353 4 3 5 15 117 114 2
-4 4 12 149 160 3 2 2 13 745 738 5 -6 1 14 103 111 1 2 6 14 62 61 2 4 5 15 194 189 2
-3 4 12 328 338 4 3 2 13 320 332 2 -5 1 14 346 355 2 3 6 14 221 202 7 -5 6 15 115 110 2
-2 4 12 602 629 4 4 2 13 62 84 2 -4 1 14 164 167 2 -9 0 15 67 64 3 -4 6 15 120 119 4
-1 4 12 562 573 4 5 2 13 181 186 2 -3 1 14 217 205 2 -7 0 15 190 186 2 -3 6 15 107 104 2
0 4 12 47 45 3 6 2 13 248 234 2 -2 1 14 374 370 2 -5 0 15 201 195 2 -2 6 15 227 226 12
1 4 12 364 376 3 7 2 13 69 66 1 -1 1 14 197 192 2 -3 0 15 354 354 4 -1 6 15 89 84 3
2 4 12 409 408 5 8 2 13 346 323 7 0 1 14 306 299 2 -1 0 15 957 940 9 0 6 15 14 16 8
3 4 12 89 89 2 -10 3 13 253 254 3 1 1 14 311 303 3 1 0 15 421 417 5 1 6 15 125 124 4
4 4 12 252 262 2 -9 3 13 348 351 3 2 1 14 416 417 3 3 0 15 49 57 3 2 6 15 86 80 2
5 4 12 189 186 4 -8 3 13 253 246 3 3 1 14 104 105 1 5 0 15 258 254 3 -10 0 16 255 248 5
6 4 12 59 70 7 -7 3 13 36 35 2 4 1 14 68 69 2 7 0 15 242 237 5 -8 0 16 260 274 3
7 4 12 18 8 8 -6 3 13 40 38 2 5 1 14 335 344 2 -10 1 15 40 42 2 -6 0 16 448 450 3
-8 5 12 55 56 2 -5 3 13 472 486 3 6 1 14 15 9 6 -9 1 15 147 150 2 -4 0 16 554 548 9
-7 5 12 41 47 3 -4 3 13 97 88 2 7 1 14 129 133 2 -8 1 15 235 236 2 -2 0 16 248 260 5
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3 0 0 16 796 813 9
-5 5 12 52 49 2 -2 3 13 113 120 2 -10 2 14 44 45 3 -6 1 15 191 193 1 2 0 16 192 196 3
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2 -7 2 16 294 300 2
4 6 12 143 136 2 4 4 13 71 77 2 -4 3 14 350 350 3 -1 2 15 253 256 2 -6 2 16 110 105 2
5 6 12 146 129 3 5 4 13 139 126 4 -3 3 14 404 416 4 0 2 15 111 112 2 -5 2 16 231 237 2
-4 7 12 95 75 2 6 4 13 287 283 10 -2 3 14 337 340 3 1 2 15 409 413 4 -4 2 16 302 298 2
-3 7 12 110 111 2 7 4 13 18 8 8 -1 3 14 380 400 3 2 2 15 482 490 3 -3 2 16 615 626 4
-2 7 12 9 4 8 -8 5 13 207 191 5 0 3 14 37 34 3 3 2 15 297 301 2 -2 2 16 303 301 2
-1 7 12 113 115 8 -7 5 13 162 165 2 1 3 14 33 22 3 4 2 15 150 155 3 -1 2 16 365 375 3
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1 7 12 128 118 2 -5 5 13 68 63 2 3 3 14 423 428 5 6 2 15 248 240 3 1 2 16 75 59 2
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-5 0 13 227 232 2 0 5 13 375 383 4 -9 4 14 7 3 7 -6 3 15 106 109 1 6 2 16 22 18 5
-3 0 13 479 460 5 1 5 13 101 96 2 -8 4 14 239 236 2 -5 3 15 433 442 3 -9 3 16 54 54 3
-1 0 13 695 682 8 2 5 13 194 199 2 -7 4 14 39 45 2 -4 3 15 59 61 2 -8 3 16 382 376 3
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5 0 13 956 990 10 5 5 13 6 3 5 -4 4 14 137 147 1 -1 3 15 94 97 2 -5 3 16 68 59 2
7 0 13 173 164 3 6 5 13 37 36 8 -3 4 14 183 184 3 0 3 15 400 409 5 -4 3 16 360 369 4
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-9 1 13 137 133 2 -5 6 13 10 14 9 -1 4 14 467 475 5 2 3 15 198 197 2 -2 3 16 501 509 4
-8 1 13 376 376 2 -4 6 13 113 107 2 0 4 14 468 471 5 3 3 15 352 358 3 -1 3 16 56 57 2
-7 1 13 94 94 1 -3 6 13 199 192 3 1 4 14 112 114 3 4 3 15 16 5

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-5 1 13 303 295 2 -1 6 13 423 417 5 3 4 14 133 141 2 6 3 15 28 18 4 2 3 16 329 340 2
-4 1 13 231 223 2 0 6 13 85 82 2 4 4 14 338 340 3 -8 4 15 105 106 2 3 3 16 14 7 6
-3 1 13 83 83 2 1 6 13 121 127 2 5 4 14 140 136 2 -7 4 15 186 179 3 4 3 16 430 434 4
-2 1 13 499 486 3 2 6 13 34 35 4 6 4 14 184 153 13 -6 4 15 221 225 2 5 3 16 142 134 2
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0 1 13 677 656 6 4 6 13 133 129 3 -7 5 14 231 213 4 -4 4 15 227 220 2 -8 4 16 18 16 3
1 1 13 283 284 2 -4 7 13 59 57 2 -6 5 14 19 12 5 -3 4 15 213 215 2 -7 4 16 313 317 3
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5 1 13 225 216 3 0 7 13 85 87 3 -2 5 14 132 131 4 1 4 15 337 353 4 -3 4 16 299 301 3
6 1 13 297 311 3 1 7 13 34 20 3 -1 5 14 411 416 4 2 4 15 295 296 3 -2 4 16 36 37 3
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-9 2 13 135 133 2 -4 0 14 116 125 3 3 5 14 282 287 3 -7 5 15 150 147 2 2 4 16 176 175 4
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-7 2 13 232 236 2 0 0 14 211 208 3 5 5 14 266 243 6 -5 5 15 103 103 2 4 4 16 212 214 2
-6 2 13 192 192 1 2 0 14 211 211 3 -6 6 14 149 137 3 -4 5 15 185 179 3 5 4 16 272 262 3
-5 2 13 159 166 1 4 0 14 200 190 3 -5 6 14 283 283 4 -3 5 15 68 74 2 -6 5 16 160 157 3
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Table 8. Observed and calculated structure factors for $C_{16}H_{14}BrNO_3S$
Page 6

h k l 10Fo 10Fc 10s h k l 10Fo 10Fc 10s h k l 10Fo 10Fc 10s h k l 10Fo 10Fc 10s h k l 10Fo 10Fc 10s

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-3 5 16 32 31 3 4 3 17 124 140 3 -3 3 18 165 173 2 -1 3 19 614 612 8 -5 0 21 177 186 3
-2 5 16 49 56 3 5 3 17 163 152 5 -2 3 18 331 331 3 0 3 19 76 83 2 -3 0 21 584 597 10
-1 5 16 257 264 3 -7 4 17 71 77 2 -1 3 18 100 99 3 1 3 19 340 346 6 -1 0 21 222 225 7
0 5 16 39 35 3 -6 4 17 12 4 11 0 3 18 249 253 4 2 3 19 34 34 2 1 0 21 132 123 2
1 5 16 370 372 7 -5 4 17 435 439 4 1 3 18 139 143 2 3 3 19 127 131 3 3 0 21 397 389 7
2 5 16 134 143 2 -4 4 17 85 83 2 2 3 18 78 69 3 4 3 19 63 72 5 -7 1 21 36 39 2
3 5 16 36 37 4 -3 4 17 112 113 3 3 3 18 246 245 3 -6 4 19 243 242 3 -6 1 21 15 16 6
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-7 0 17 27 19 3 -5 5 17 61 60 2 0 4 18 253 263 2 -3 5 19 166 162 4 3 1 21 52 36 2
-5 0 17 363 361 4 -4 5 17 252 242 7 1 4 18 33 31 3 -1 5 19 90 90 3 -6 2 21 355 344 4
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-1 0 17 73 78 3 -2 5 17 199 206 3 3 4 18 61 55 2 -8 0 20 193

186 5 -4 2 21 293 292 4
1 0 17 307 315 6 -1 5 17 30 30 3 -5 5 18 135 128 2 -6 0 20 264 262 3 -3 2 21 266 272 5
3 0 17 110 138 3 0 5 17 181 175 2 -4 5 18 138 137 2 -4 0 20 219 230 4 -2 2 21 57 54 5
5 0 17 188 187 4 1 5 17 103 109 2 -3 5 18 343 355 14 -2 0 20 451 446 5 -1 2 21 39 33 3
-9 1 17 46 46 2 2 5 17 227 217 3 -2 5 18 11 1 11 0 0 20 100 98 4 0 2 21 400 409 4
-8 1 17 24 20 3 3 5 17 94 86 2 -1 5 18 102 100 4 2 0 20 222 213 4 1 2 21 209 219 3
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-1 1 17 324 336 2 2 0 18 356 355 4 1 0 19 394 399 6 -2 1 20 267 281 3 0 3 21 154 148 4
0 1 17 198 203 2 4 0 18 125 106 3 3 0 19 673 679 6 -1 1 20 182 177 2 1 3 21 442 433 6
1 1 17 85 85 2 -9 1 18 190 186 2 5 0 19 106 86 5 0 1 20 360 371 3 -6 0 22 527 503 12
2 1 17 277 291 2 -8 1 18 247 240 3 -8 1 19 339 337 4 1 1 20 32 28 3 -4 0 22 105 98 2
3 1 17 302 301 2 -7 1 18 184 190 2 -7 1 19 183 182 2 2 1 20 166 179 2 -2 0 22 398 414 6
4 1 17 49 36 2 -6 1 18 242 244 2 -6 1 19 2 9 1 3 1 20 145 146 1 0 0 22 505 500 9
5 1 17 242 247 5 -5 1 18 386 393 3 -5 1 19 222 220 2 4 1 20 188 184 2 2 0 22 246 268 5
6 1 17 139 125 3 -4 1 18 16 12 6 -4 1 19 398 393 3 -7 2 20 152 144 4 -6 1 22 51 59 2
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-8 2 17 253 249 3 -2 1 18 66 69 2 -2 1 19 261 245 4 -5 2 20 261 254 2 -4 1 22 313 317 3
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3 -2 1 22 213 212 7
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-4 2 17 24 11 4 2 1 18 208 207 3 2 1 19 576 581 4 -1 2 20 194
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-3 2 17 40 36 3 3 1 18 83 77 3 3 1 19 66 71 3 0 2 20 98 107
2 1 1 22 267 236 4
-2 2 17 625 639 6 4 1 18 269 267 2 4 1 19 279 277 6 1 2 20 327
331 3 2 1 22 261 253 4
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141 2 -5 2 22 375 392 4
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2 -4 2 22 129 128 2
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103 3 -3 2 22 443 449 8
2 2 17 239 240 2 -6 2 18 180 176 2 -6 2 19 330 324 3 -5 3 20 228
232 2 -2 2 22 179 180 6
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154 2 -1 2 22 71 76 3
4 2 17 240 237 2 -4 2 18 147 144 2 -4 2 19 201 197 3 -3 3 20 288
290 3 0 2 22 222 213 3
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121 3 1 2 22 336 334 4
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141 5 -3 3 22 143 157 3
-8 3 17 12 10 6 -1 2 18 295 296 4 -1 2 19 335 322 4 0 3 20 184
192 3 -2 3 22 95 91 3
-7 3 17 15 15 5 0 2 18 113 111 2 0 2 19 464 461 4 1 3 20 275
283 2 -1 3 22 48 50 4
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37 2 -4 1 23 188 189 3
-3 3 17 76 80 2 4 2 18 177 166 2 4 2 19 244 240 3 -4 4 20 258
257 3 -3 1 23 232 239 3
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109 3 -1 1 23 71 61 2
-1 3 17 249 265 3 -8 3 18 309 301 4 -6 3 19 59 55 2 -2 4 20 343
355 8 0 1 23 250 260 4
0 3 17 133 125 2 -7 3 18 21 20 4 -5 3 19 387 387 3 -1 4 20 130
127 2
1 3 17 115 121 2 -6 3 18 380 378 6 -4 3 19 54 53 2 0 4 20 71 81
2
2 3 17 141 135 3 -5 3 18 42 49 2 -3 3 19 82 94 3 1 4 20 53 53 2

Crystal Structure Report

for

$C_{19}H_{19}BrNO_5S$

Compound 3. 54a

Contents

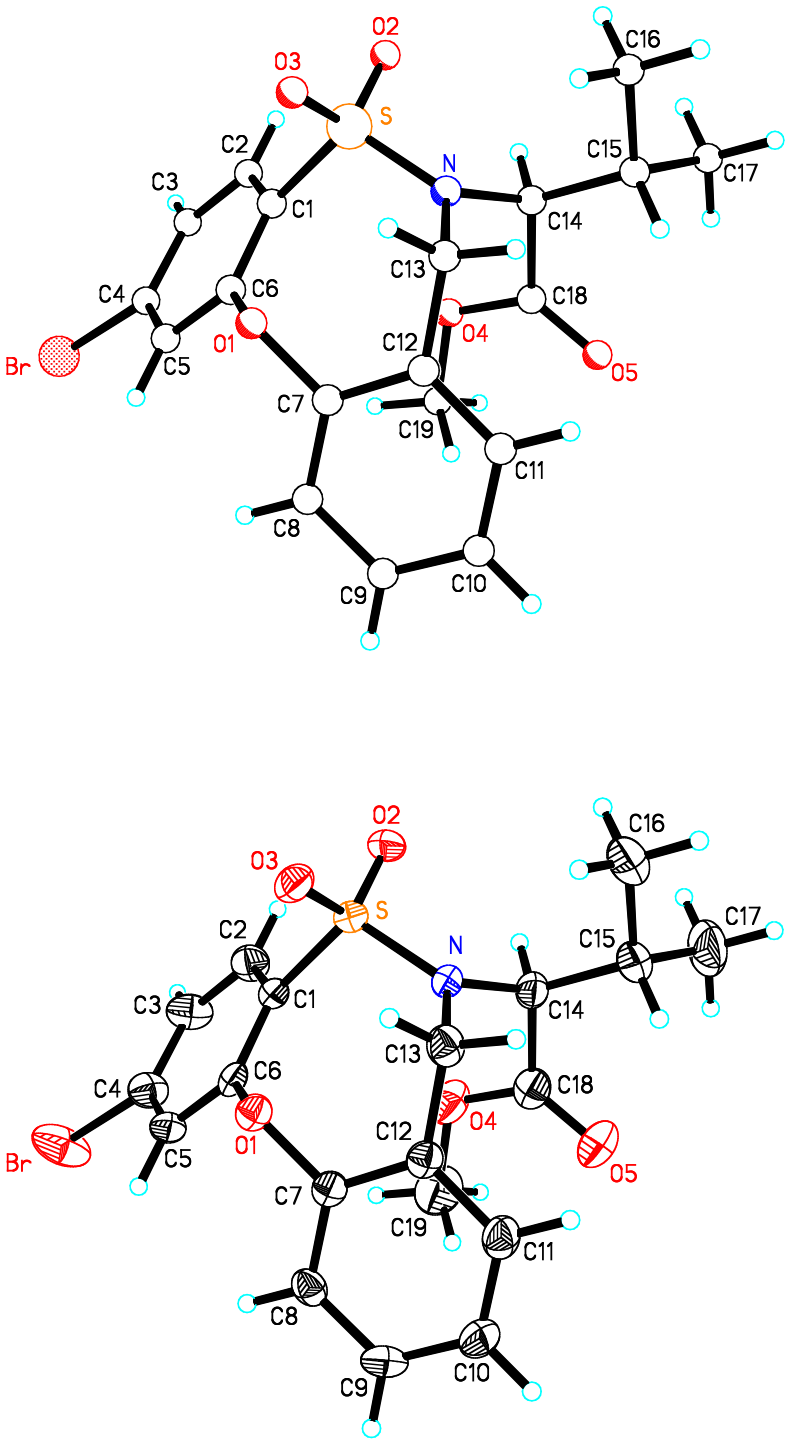
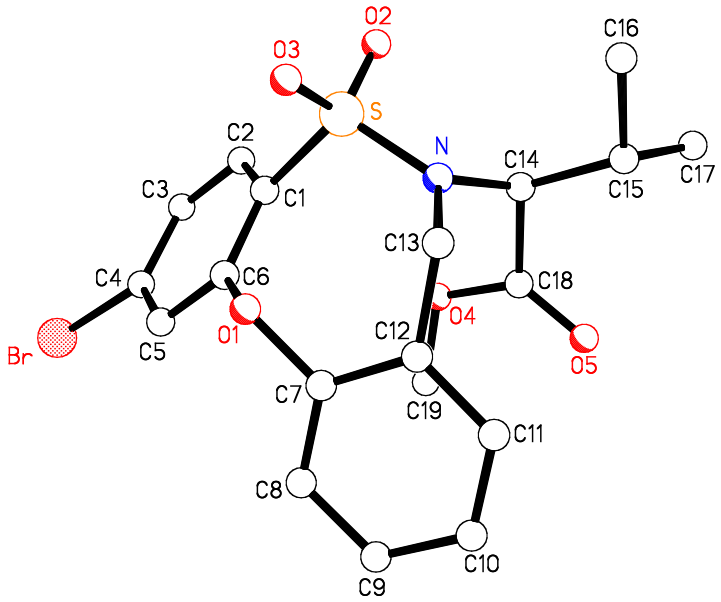


Figure 1. 50% Probability Ellipsoid Drawing of **3.54a**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O3
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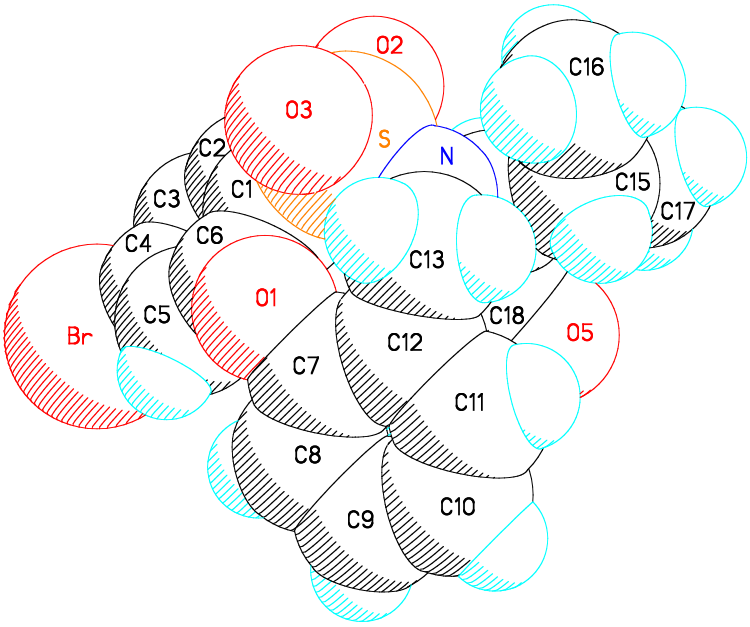
C2
N
C14
C17
C3
C1
C15
C13
C4
C6
C18
O4
O1
C12
O5
Br
C5
C7
C19
C11
C8
C10
C9


O2
C16
O3
S
N
C2
C1
C15
C3
C17
C4
C6
C13
O1
C5
C18
O5
Br
C12
C7
C11
C8
C9
C10

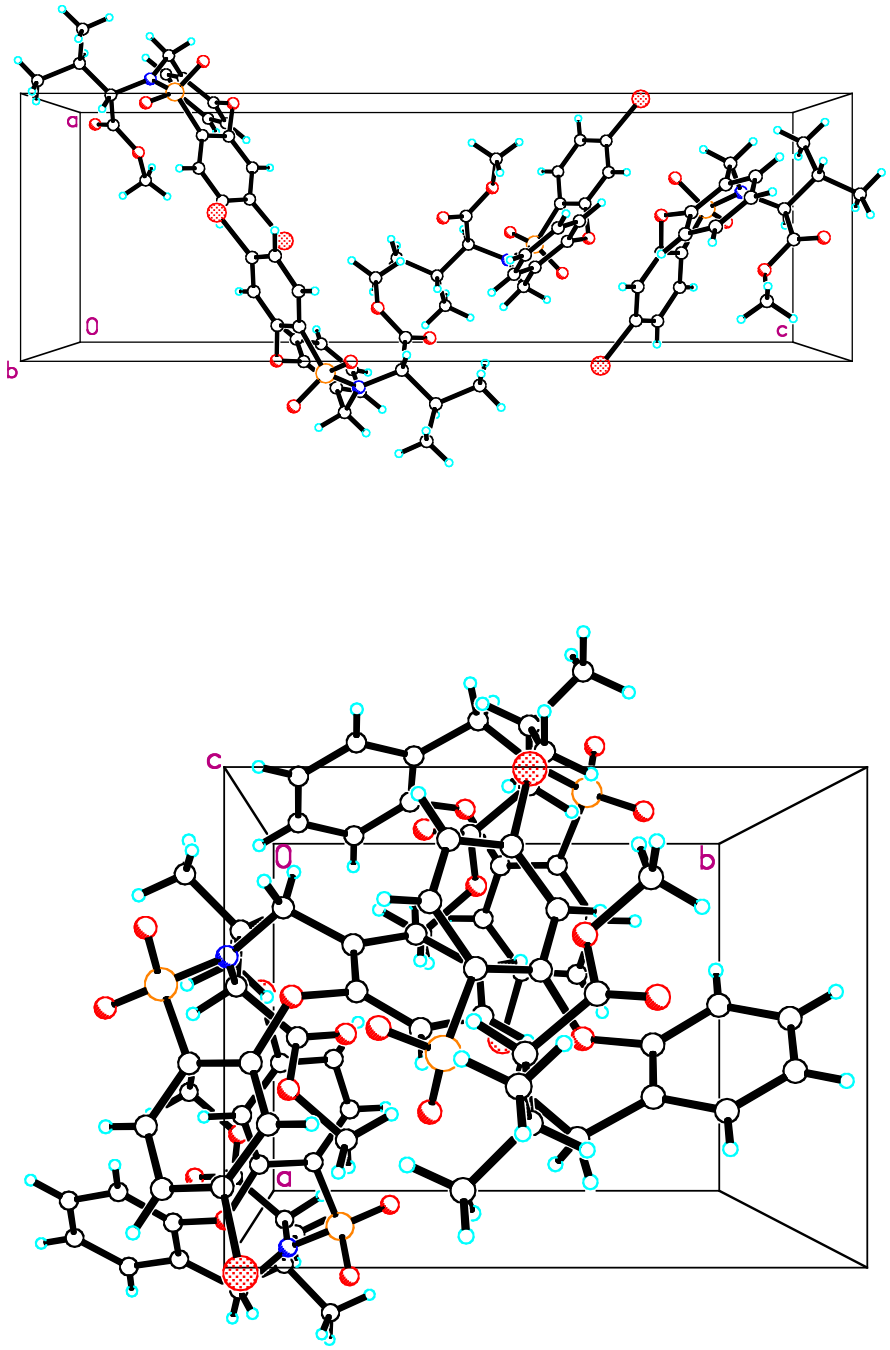


Figure 2. Crystal packing diagrams of 3.5

Comments

The asymmetric unit contains one $C_{19}H_{19}BrNO_5S$ molecule. All displacement ellipsoids are drawn at the 50% probability level.

Brief Experimental Description to be Included as Text or as a Footnote at Time of Publication

Colorless parallelepiped-shaped crystals of $C_{19}H_{19}BrNO_5S$ are, at 100(2) K, orthorhombic, space group $P2_12_12_1 - D_2^4$ (No. 19)[1] with **a** = 7.965(2) Å, **b** = 10.191(2) Å, **c** = 24.500(6) Å, V = 1988.7(8) Å^3 and Z = 4 molecules {d_{calcd} = 1.514 g/cm^3; $_a$(MoK) = 2.201 mm^{-1}}. A full hemisphere of diffracted intensities (1850 30-second frames with a scan width of 0.30) was measured for a single-domain specimen using graphite-monochromated MoK radiation (= 0.71073 Å) on a Bruker SMART APEX CCD Single Crystal Diffraction System[2]. X-rays were provided by a fine-focus sealed x-ray tube operated at 50kV and 30mA. Lattice constants were determined with the Bruker SAINT software package using peak centers for 1571 reflections. A total of 20488 integrated reflection intensities having 2(MoK)< 57.40 were produced using the Bruker program SAINT[3]; 5117 of these were unique and gave R_{int} = 0.093 with a coverage which was 99.6% complete. The data were corrected empirically for variable absorption effects using equivalent reflections; the relative transmission factors ranged from 0.930 to 1.000. The Bruker software package SHELXTL was used to solve the structure using "direct methods" techniques. All stages of weighted full-matrix least-squares refinement were conducted using F_o^2 data with the SHELXTL Version 6.10 software package[4].

The final structural model incorporated anisotropic thermal parameters for all nonhydrogen atoms and isotropic thermal parameters for all hydrogen atoms. All hydrogen atoms were located in a difference Fourier and included in the structural model as independent isotropic atoms whose parameters were allowed to vary in least-squares refinement cycles. A total of 320 parameters were refined using no restraints, 5117 data and weights of w = 1/ [^{2}(F^2) + (0.0364 P)^2], where P = [F_O^2 + 2F_C^2] / 3. Final agreement factors at convergence are: R_1(unweighted, based on F) = 0.058 for 3567 independent absorption-corrected "observed" reflections having 2(MoK)< 57.40 and I>2(I); R_1(unweighted, based on F) = 0.096 and wR_2(weighted, based on F^2) = 0.108 for all 5117 independent absorption-corrected reflections having 2(MoK)< 57.40. The largest shift/s.u. was 0.001 in the final refinement cycle. The final difference map had maxima and minima of 0.56 and -0.50 e$^-$/Å^3, respectively. The absolute configuration was established experimentally using anomalous dispersion of the x-rays; the Flack absolute structure parameter refined to a final value of 0.01(1).

Acknowledgment

The authors thank the National Science Foundation (grant CHE-0079282) and the University of Kansas for funds to purchase the x-ray instrument and computers.

References

(1) International **Table** s for Crystallography, Vol A, 4th ed., Kluwer: Boston (1996).

(2) Data Collection: SMART Software Reference Manual (1998). Bruker-AXS, 5465 E. Cheryl Parkway, Madison, WI 53711-5373 USA.

(3) Data Reduction: SAINT Software Reference Manual (1998). Bruker-AXS, 6300 Enterprise Dr., Madison, WI 53719-1173, USA.

(4) G. M. Sheldrick (2000). SHELXTL Version 6.10 Reference Manual. Bruker-AXS, 5465 E. Cheryl Parkway, Madison, WI 53711-5373 USA.

Table 1. Crystal data and structure refinement for $C_{19}H_{19}BrNO_5S$.

Empirical formula	$C_{19}H_{19}BrNO_5S$	
Formula weight	453.32	
Temperature	100(2) K	
Wavelength	0.71073 Å	
Crystal system	Orthorhombic	
Space group	$P2_12_12_1 - D_2^4$ (No. 19)	
Unit cell dimensions	**a** = 7.965(2) Å	= 90.000°
	b = 10.191(2) Å	= 90.000°
	c = 24.500(6) Å	= 90.000°
Volume	1988.7(8) $Å^3$	
Z	4	
Density (calculated)	1.514 Mg/m^3	
Absorption coefficient	2.201 mm^{-1}	
F(000)	924	
Crystal size	0.09 x 0.05 x 0.05 mm^3	
Theta range for data collection	3.88° to 28.70°	
Index ranges	-10 h 10, -13 k 13, -33 l 31	
Reflections collected	20488	
Independent reflections	5117 [R_{int} = 0.093]	
Completeness to theta = 28.70°	99.6 %	
Absorption correction	Multi-scan	
Max. and min. transmission	1.000 and 0.930	
Refinement method	Full-matrix least-squares on F^2	
Data / restraints / parameters	5117 / 0 / 320	
Goodness-of-fit on F^2	0.989	
Final R indices [I>2sigma(I)]	R_1 = 0.058, wR_2 = 0.097	
R indices (all data)	R_1 = 0.096, wR_2 = 0.108	
Absolute structure parameter	0.009(12)	
Largest diff. peak and hole	0.56 and -0.50 $e^-/Å^3$	

$R_1 = \| |F_o| - |F_c| \| / |F_o|$

$wR_2 = \{ [w(F_o^2 - F_c^2)^2] / [w(F_o^2)^2] \}^{1/2}$

Table 2. Atomic coordinates (x 10^4) and equivalent isotropic displacement parameters ($Å^2$ x 10^3)
for $C_{19}H_{19}BrNO_5S$. U(eq) is defined as one third of the trace of the orthogonalized U_{ij} tensor.

_	x	y	z	U(eq)
Br	10593(1)	40(1)	7865(1)	54(1)
S	4236(1)	-1535(1)	6410(1)	23(1)
O(1)	4534(3)	862(2)	7110(1)	23(1)
O(2)	4780(4)	-2607(3)	6072(1)	30(1)
O(3)	2955(4)	-1748(3)	6810(1)	30(1)
O(4)	6707(4)	720(3)	5774(1)	36(1)
O(5)	5401(4)	1754(3)	5089(1)	39(1)
N	3573(4)	-391(3)	6007(1)	22(1)
C(1)	6054(5)	-981(4)	6761(2)	22(1)
C(2)	7495(6)	-1751(4)	6748(2)	29(1)
C(3)	8889(5)	-1436(4)	7057(2)	32(1)
C(4)	8786(5)	-327(4)	7391(2)	30(1)
C(5)	7385(6)	471(4)	7397(2)	26(1)
C(6)	6027(4)	141(4)	7078(2)	20(1)
C(7)	4413(5)	1996(4)	6782(2)	21(1)
C(8)	5260(5)	3127(4)	6912(2)	25(1)
C(9)	4977(6)	4239(4)	6600(2)	31(1)
C(10)	3867(6)	4211(5)	6170(2)	33(1)
C(11)	3043(6)	3064(4)	6040(2)	29(1)
C(12)	3319(5)	1922(4)	6343(2)	22(1)
C(13)	2446(5)	655(4)	6212(2)	26(1)
C(14)	4255(6)	-278(4)	5450(2)	27(1)
C(15)	2889(7)	-242(5)	5009(2)	36(1)
C(16)	1511(9)	-1267(6)	5126(2)	49(2)
C(17)	3657(10)	-474(7)	4445(2)	57(2)
C(18)	5485(6)	858(4)	5410(2)	30(1)
C(19)	7895(7)	1789(6)	5813(3)	46(1)

Table 3. Bond lengths [Å] for $C_{19}H_{19}BrNO_5S$.

Br-C(4)	1.886(4)
S-O(3)	1.431(3)
S-O(2)	1.438(3)
S-N	1.617(3)
S-C(1)	1.775(4)
O(1)-C(6)	1.400(4)
O(1)-C(7)	1.411(4)
O(4)-C(18)	1.327(5)
O(4)-C(19)	1.446(6)
O(5)-C(18)	1.206(5)
N-C(14)	1.473(5)
N-C(13)	1.481(5)
C(1)-C(6)	1.383(5)
C(1)-C(2)	1.391(6)
C(2)-C(3)	1.383(6)
C(2)-H(2)	1.01(4)
C(3)-C(4)	1.398(6)
C(4)-C(5)	1.380(6)
C(5)-C(6)	1.375(5)
C(5)-H(5)	0.84(4)
C(7)-C(8)	1.373(6)
C(7)-C(12)	1.386(6)
C(8)-C(9)	1.386(6)
C(8)-H(8)	0.84(4)
C(9)-C(10)	1.375(6)
C(9)-H(9)	0.84(4)
C(10)-C(11)	1.378(7)
C(10)-H(10)	0.87(4)
C(11)-C(12)	1.398(6)
C(11)-H(11)	0.91(4)
C(12)-C(13)	1.501(6)
C(13)-H(13A)	0.98(4)

C(13)-H(13B)	0.88(4)
C(14)-C(18)	1.521(6)
C(14)-C(15)	1.533(6)
C(14)-H(14)	1.01(3)
C(15)-C(17)	1.529(7)
C(15)-C(16)	1.542(7)
C(15)-H(15)	0.92(3)
C(16)-H(16A)	1.07(5)
C(16)-H(16B)	0.95(5)
C(16)-H(16C)	1.00(5)
C(17)-H(17A)	1.00(7)
C(17)-H(17B)	0.85(5)
C(17)-H(17C)	1.05(6)
C(19)-H(19A)	0.90(4)
C(19)-H(19B)	0.99(5)
C(19)-H(19C)	1.01(5)

Table 4. Bond angles [°] for $C_{19}H_{19}BrNO_5S$.

O(3)-S-O(2)	119.6(2)
O(3)-S-N	107.1(2)
O(2)-S-N	107.2(2)
O(3)-S-C(1)	107.4(2)
O(2)-S-C(1)	105.9(2)
N-S-C(1)	109.4(2)
C(6)-O(1)-C(7)	117.1(3)
C(18)-O(4)-C(19)	116.4(4)
C(14)-N-C(13)	118.8(3)
C(14)-N-S	120.1(3)
C(13)-N-S	120.6(3)
C(6)-C(1)-C(2)	119.5(4)
C(6)-C(1)-S	121.5(3)
C(2)-C(1)-S	118.8(3)
C(3)-C(2)-C(1)	121.2(4)
C(3)-C(2)-H(2)	122(2)
C(1)-C(2)-H(2)	116(2)
C(2)-C(3)-C(4)	117.5(4)
C(5)-C(4)-C(3)	121.9(4)
C(5)-C(4)-Br	119.6(3)
C(3)-C(4)-Br	118.4(3)
C(6)-C(5)-C(4)	119.1(4)
C(6)-C(5)-H(5)	121(3)
C(4)-C(5)-H(5)	120(3)
C(5)-C(6)-C(1)	120.6(4)
C(5)-C(6)-O(1)	120.5(3)
C(1)-C(6)-O(1)	118.7(3)
C(8)-C(7)-C(12)	122.3(4)
C(8)-C(7)-O(1)	121.4(4)
C(12)-C(7)-O(1)	116.2(3)
C(7)-C(8)-C(9)	118.6(4)
C(7)-C(8)-H(8)	124(3)
C(9)-C(8)-H(8)	117(3)

C(10)-C(9)-C(8)	120.7(4)
C(10)-C(9)-H(9)	119(2)
C(8)-C(9)-H(9)	120(2)
C(9)-C(10)-C(11)	120.0(4)
C(9)-C(10)-H(10)	118(3)
C(11)-C(10)-H(10)	122(3)
C(10)-C(11)-C(12)	120.6(4)
C(10)-C(11)-H(11)	122(2)
C(12)-C(11)-H(11)	117(2)
C(7)-C(12)-C(11)	117.8(4)
C(7)-C(12)-C(13)	120.2(4)
C(11)-C(12)-C(13)	122.0(4)
N-C(13)-C(12)	114.3(3)
N-C(13)-H(13A)	105(2)
C(12)-C(13)-H(13A)	111(2)
N-C(13)-H(13B)	104(3)
C(12)-C(13)-H(13B)	108(3)
H(13A)-C(13)-H(13B)	116(4)
N-C(14)-C(18)	110.9(3)
N-C(14)-C(15)	113.2(4)
C(18)-C(14)-C(15)	113.2(3)
N-C(14)-H(14)	105(2)
C(18)-C(14)-H(14)	109(2)
C(15)-C(14)-H(14)	105(2)
C(17)-C(15)-C(14)	110.4(5)
C(17)-C(15)-C(16)	110.3(5)
C(14)-C(15)-C(16)	111.0(4)
C(17)-C(15)-H(15)	110(2)
C(14)-C(15)-H(15)	107(2)
C(16)-C(15)-H(15)	108(2)
C(15)-C(16)-H(16A)	112(3)
C(15)-C(16)-H(16B)	102(3)
H(16A)-C(16)-H(16B)	105(4)
C(15)-C(16)-H(16C)	114(2)
H(16A)-C(16)-H(16C)	111(4)
H(16B)-C(16)-H(16C)	112(4)

C(15)-C(17)-H(17A)	113(4)
C(15)-C(17)-H(17B)	112(3)
H(17A)-C(17)-H(17B)	108(5)
C(15)-C(17)-H(17C)	110(3)
H(17A)-C(17)-H(17C)	103(5)
H(17B)-C(17)-H(17C)	110(4)
O(5)-C(18)-O(4)	124.0(4)
O(5)-C(18)-C(14)	125.6(4)
O(4)-C(18)-C(14)	110.4(3)
O(4)-C(19)-H(19A)	105(3)
O(4)-C(19)-H(19B)	105(3)
H(19A)-C(19)-H(19B)	113(4)
O(4)-C(19)-H(19C)	109(3)
H(19A)-C(19)-H(19C)	109(4)
H(19B)-C(19)-H(19C)	115(4)

Table 5. Anisotropic displacement parameters ($Å^2 x\ 10^3$) for $C_{19}H_{19}BrNO_5S$. The anisotropic
displacement factor exponent takes the form: $-2^2[\ h^2\ a^{*2}U_{11} + ...\ + 2\ h\ k\ a^*\ b^*\ U_{12}$

	U_{11}	U_{22}	U_{33}	U_{23}	U_{13}	U_{12}
Br	34(1)	46(1)	82(1)	-22(1)	-28(1)	9(1)
S	27(1)	19(1)	24(1)	2(1)	-2(1)	-3(1)
O(1)	23(1)	23(1)	23(1)	1(1)	2(1)	5(1)
O(2)	40(2)	18(2)	31(2)	-2(1)	-7(1)	-1(1)
O(3)	32(2)	28(2)	28(2)	8(1)	-2(1)	-6(1)
O(4)	30(2)	42(2)	37(2)	14(2)	-2(2)	-4(2)
O(5)	43(2)	39(2)	36(2)	15(2)	4(2)	2(2)
N	28(2)	19(2)	19(2)	2(1)	-2(2)	1(1)
C(1)	25(2)	18(2)	21(2)	3(2)	-2(2)	-3(2)
C(2)	32(3)	25(2)	30(3)	-3(2)	0(2)	4(2)
C(3)	28(2)	26(2)	43(3)	-3(2)	-2(2)	1(2)
C(4)	21(2)	30(3)	39(3)	-1(2)	-6(2)	-2(2)
C(5)	33(3)	19(2)	25(2)	-5(2)	1(2)	2(2)
C(6)	23(2)	20(2)	18(2)	6(2)	2(2)	3(2)
C(7)	25(2)	20(2)	19(2)	-3(2)	5(2)	10(2)
C(8)	25(2)	27(2)	22(2)	-6(2)	-2(2)	4(2)
C(9)	37(3)	16(2)	40(3)	-7(2)	-1(2)	-3(2)
C(10)	45(3)	22(2)	33(3)	4(2)	-4(2)	8(2)
C(11)	30(3)	29(3)	28(3)	0(2)	-4(2)	9(2)
C(12)	23(2)	22(2)	22(2)	0(2)	1(2)	5(2)
C(13)	24(2)	30(2)	24(2)	1(2)	-5(2)	6(2)
C(14)	39(2)	23(2)	20(2)	0(2)	-2(2)	3(2)
C(15)	49(3)	31(3)	26(3)	-3(2)	-7(2)	-4(2)
C(16)	66(4)	51(4)	30(3)	-3(3)	-11(3)	-18(3)
C(17)	82(5)	63(5)	25(3)	-9(3)	-15(3)	12(4)
C(18)	34(3)	31(2)	25(2)	-1(2)	6(2)	11(2)
C(19)	29(3)	59(4)	51(4)	14(3)	0(3)	-12(3)

Table 6. Hydrogen coordinates (x 10^4) and isotropic displacement parameters (Å^{2}x 10^3) for $C_{19}H_{19}BrNO_5S$.

__	x	y	z	U(eq)
H(2)	7420(50)	-2600(40)	6535(14)	13(10)
H(5)	7330(40)	1090(40)	7621(14)	7(10)
H(8)	5930(50)	3200(40)	7176(16)	16(11)
H(9)	5450(40)	4940(40)	6682(12)	6(8)
H(10)	3750(50)	4920(50)	5976(16)	29(12)
H(11)	2270(50)	3020(30)	5767(15)	9(10)
H(13A)	1930(50)	280(40)	6541(17)	28(12)
H(13B)	1760(50)	800(40)	5938(16)	18(11)
H(14)	4890(40)	-1130(30)	5384(14)	5(9)
H(15)	2400(50)	570(40)	5025(14)	1(9)
H(16A)	570(70)	-1280(40)	4810(20)	53(14)
H(16B)	2110(70)	-2070(50)	5080(20)	47(17)
H(16C)	1000(60)	-1190(40)	5500(20)	37(14)
H(17A)	4320(100)	-1310(70)	4420(30)	110(30)
H(17B)	2920(60)	-490(40)	4195(19)	27(13)
H(17C)	4550(70)	250(50)	4360(20)	68(19)
H(19A)	8520(50)	1610(40)	6108(18)	22(12)
H(19B)	8540(60)	1750(40)	5470(20)	35(13)
H(19C)	7260(70)	2630(50)	5880(20)	56(17)

Table 7. Torsion angles [°] for $C_{19}H_{19}BrNO_5S$.

O(3)-S-N-C(14)	-157.0(3)
O(2)-S-N-C(14)	-27.5(3)
C(1)-S-N-C(14)	86.9(3)
O(3)-S-N-C(13)	31.0(3)
O(2)-S-N-C(13)	160.4(3)
C(1)-S-N-C(13)	-85.2(3)
O(3)-S-C(1)-C(6)	-58.4(4)
O(2)-S-C(1)-C(6)	172.8(3)
N-S-C(1)-C(6)	57.5(4)
O(3)-S-C(1)-C(2)	116.6(3)
O(2)-S-C(1)-C(2)	-12.2(4)
N-S-C(1)-C(2)	-127.4(3)
C(6)-C(1)-C(2)-C(3)	1.7(7)
S-C(1)-C(2)-C(3)	-173.4(3)
C(1)-C(2)-C(3)-C(4)	1.1(7)
C(2)-C(3)-C(4)-C(5)	-3.0(7)
C(2)-C(3)-C(4)-Br	174.6(3)
C(3)-C(4)-C(5)-C(6)	2.2(7)
Br-C(4)-C(5)-C(6)	-175.5(3)
C(4)-C(5)-C(6)-C(1)	0.7(6)
C(4)-C(5)-C(6)-O(1)	174.3(4)
C(2)-C(1)-C(6)-C(5)	-2.7(6)
S-C(1)-C(6)-C(5)	172.3(3)
C(2)-C(1)-C(6)-O(1)	-176.3(4)
S-C(1)-C(6)-O(1)	-1.4(5)
C(7)-O(1)-C(6)-C(5)	86.0(4)
C(7)-O(1)-C(6)-C(1)	-100.3(4)
C(6)-O(1)-C(7)-C(8)	-74.7(4)
C(6)-O(1)-C(7)-C(12)	109.0(4)
C(12)-C(7)-C(8)-C(9)	1.6(6)
O(1)-C(7)-C(8)-C(9)	-174.5(4)
C(7)-C(8)-C(9)-C(10)	0.2(6)
C(8)-C(9)-C(10)-C(11)	-1.0(7)

C(9)-C(10)-C(11)-C(12)	0.2(7)
C(8)-C(7)-C(12)-C(11)	-2.3(6)
O(1)-C(7)-C(12)-C(11)	173.9(4)
C(8)-C(7)-C(12)-C(13)	178.9(4)
O(1)-C(7)-C(12)-C(13)	-4.8(5)
C(10)-C(11)-C(12)-C(7)	1.4(6)
C(10)-C(11)-C(12)-C(13)	-179.8(4)
C(14)-N-C(13)-C(12)	-72.7(5)
S-N-C(13)-C(12)	99.5(4)
C(7)-C(12)-C(13)-N	-68.8(5)
C(11)-C(12)-C(13)-N	112.5(5)
C(13)-N-C(14)-C(18)	67.9(5)
S-N-C(14)-C(18)	-104.3(3)
C(13)-N-C(14)-C(15)	-60.4(5)
S-N-C(14)-C(15)	127.4(3)
N-C(14)-C(15)-C(17)	-165.7(4)
C(18)-C(14)-C(15)-C(17)	67.1(5)
N-C(14)-C(15)-C(16)	-43.1(6)
C(18)-C(14)-C(15)-C(16)	-170.3(4)
C(19)-O(4)-C(18)-O(5)	6.2(6)
C(19)-O(4)-C(18)-C(14)	-175.0(4)
N-C(14)-C(18)-O(5)	-124.9(4)
C(15)-C(14)-C(18)-O(5)	3.5(6)
N-C(14)-C(18)-O(4)	56.4(4)
C(15)-C(14)-C(18)-O(4)	-175.2(4)

Table 8. Observed and calculated structure factors for $C_{19}H_{19}BrNO_5S$
Page 1

h k l 10Fo 10Fc 10s h k l 10Fo 10Fc 10s h k l 10Fo 10Fc 10s h k l 10Fo 10Fc 10s h k l 10Fo 10Fc 10s

2 0 0 1129 1079 18 5 9 0 206 219 11 3 3 1 493 485 6 -8 8 1 83 88 82 10 0 2 123 109 64
4 0 0 119 122 12 6 9 0 66 18 56 4 3 1 915 932 11 -7 8 1 177 178 18 -10 1 2 52 40 52
6 0 0 602 625 12 7 9 0 168 149 18 5 3 1 163 156 8 -6 8 1 133 135 18 -9 1 2 111 101 27
8 0 0 419 433 17 8 9 0 182 171 15 6 3 1 579 591 8 -5 8 1 113 100 17 -8 1 2 114 123 16
10 0 0 175 195 41 0 10 0 168 166 23 7 3 1 54 64 42 -4 8 1 212 223 10 -7 1 2 544 562 11
2 1 0 390 388 5 1 10 0 0 28 1 8 3 1 70 82 70 -3 8 1 270 266 10 -6 1 2 128 125 10
3 1 0 972 981 11 2 10 0 242 219 13 9 3 1 84 42 72 -2 8 1 90 106 18 -5 1 2 779 783 10
4 1 0 466 469 7 3 10 0 53 11 53 10 3 1 196 166 31 -1 8 1 634 631 11 -4 1 2 397 393 6
5 1 0 870 905 11 4 10 0 88 64 30 -10 4 1 61 53 61 0 8 1 303 304 11 -3 1 2 830 852 10
6 1 0 162 158 9 5 10 0 0 56 1 -9 4 1 262 262 23 1 8 1 574 600 11 -2 1 2 693 691 10
7 1 0 386 395 13 6 10 0 51 26 51 -8 4 1 191 180 24 2 8 1 99 121 16 2 1 2 684 696 9
8 1 0 62 39 61 7 10 0 135 80 22 -7 4 1 430 428 12 3 8 1 233 231 14 3 1 2 823 833 9
9 1 0 64 100 64 1 11 0 78 16 34 -6 4 1 302 296 9 4 8 1 187 214 14 4 1 2 394 379 6
10 1 0 0 4 1 2 11 0 0 75 1 -5 4 1 360 363 16 5 8 1 103 121 19 5 1 2 773 794 10
0 2 0 1694 1708 49 3 11 0 32 89 31 -4 4 1 321 301 7 6 8 1 113 115 18 6 1 2 135 143 10
1 2 0 210 222 6 4 11 0 32 26 31 -3 4 1 410 405 7 7 8 1 183 182 17 7 1 2 545 574 11
2 2 0 573 582 7 5 11 0 177 200 20 -2 4 1 417 425 7 8 8 1 102 78 27 8 1 2 150 158 15
3 2 0 200 194 6 6 11 0 141 99 27 -1 4 1 987 989 11 -8 9 1 99 91 36 9 1 2 92 114 91
4 2 0 425 395 7 0 12 0 364 365 28 0 4 1 734 700 9 -7 9 1 0 22 1 10 1 2 88 23 87
5 2 0 124 98 9 1 12 0 7 22 7 1 4 1 985 975 11 -6 9 1 171 164 15 -10 2 2 133 129 33

6 2 0 425 424 8 2 12 0 336 288 17 2 4 1 444 446 6 -5 9 1 111 107 16 -9 2 2 106 136 76
7 2 0 225 223 10 3 12 0 69 43 69 3 4 1 395 374 6 -4 9 1 400 384 10 -8 2 2 233 222 15
8 2 0 182 159 18 4 12 0 176 104 22 4 4 1 300 271 9 -3 9 1 135 113 16 -7 2 2 279 284 11
9 2 0 101 138 48 5 12 0 87 99 86 5 4 1 316 335 9 -2 9 1 438 454 12 -6 2 2 354 351 7
10 2 0 249 184 35 1 13 0 72 45 72 6 4 1 307 308 9 -1 9 1 171 174 15 -5 2 2 318 318 6
1 3 0 423 428 6 2 13 0 82 72 52 7 4 1 440 436 13 0 9 1 623 639 14 -4 2 2 85 93 9
2 3 0 482 482 7 3 13 0 37 71 37 8 4 1 180 176 14 1 9 1 170 164 19 -3 2 2 621 630 7
3 3 0 327 324 6 2 0 1 921 922 11 9 4 1 330 283 21 2 9 1 452 468 12 -2 2 2 976 962 11
4 3 0 315 292 7 3 0 1 245 205 6 10 4 1 103 51 46 3 9 1 100 96 16 -1 2 2 431 436 6
5 3 0 541 560 7 4 0 1 189 192 7 -10 5 1 143 82 35 4 9 1 372 383 13 0 2 2 937 942 15
6 3 0 26 2 25 5 0 1 307 317 7 -9 5 1 153 149 31 5 9 1 123 107 19 1 2 2 421 424 6
7 3 0 174 197 13 6 0 1 179 173 8 -8 5 1 66 36 66 6 9 1 183 165 19 2 2 2 1004 1016 12
8 3 0 120 94 45 7 0 1 153 166 11 -7 5 1 53 59 52 7 9 1 84 20 43 3 2 2 627 617 9
9 3 0 81 75 81 8 0 1 99 131 19 -6 5 1 340 344 10 8 9 1 90 82 42 4 2 2 88 96 13
10 3 0 49 95 49 9 0 1 114 163 38 -5 5 1 215 216 10 -7 10 1 218 202 16 5 2 2 275 295 9
0 4 0 700 660 12 10 0 1 66 68 65 -4 5 1 642 646 9 -6 10 1 83 102 33 6 2 2 364 349 9
1 4 0 125 97 8 -10 1 1 151 101 46 -3 5 1 332 318 7 -5 10 1 92 65 23 7 2 2 281 277 10
2 4 0 432 449 7 -9 1 1 198 193 17 -2 5 1 183 195 8 -4 10 1 170 143 20 8 2 2 258 264 23
3 4 0 97 87 14 -8 1 1 45 39 44 -1 5 1 342 336 6 -3 10 1 201 169 18 9 2 2 142 138 34
4 4 0 192 195 7 -7 1 1 223 225 11 0 5 1 90 97 10 -2 10 1 151 135 28 10 2 2 138 156 56
5 4 0 195 185 9 -6 1 1 391 386 8 1 5 1 355 338 8 -1 10 1 234 213 13 -10 3 2 0 79 1
6 4 0 139 142 12 -5 1 1 159 146 8 2 5 1 225 236 7 0 10 1 178 173 15 -9 3 2 61 39 61
7 4 0 202 200 13 -4 1 1 579 592 7 3 5 1 333 332 8 1 10 1 212 202 14 -8 3 2 314 300 20

8 4 0 205 192 24 -3 1 1 53 42 16 4 5 1 641 652 9 2 10 1 88 122 45 -7 3 2 149 133 18
9 4 0 0 15 1 -2 1 1 514 523 8 5 5 1 222 219 9 3 10 1 195 180 18 -6 3 2 381 382 8
10 4 0 173 152 28 2 1 1 546 554 6 6 5 1 341 380 12 4 10 1 136 145 20 -5 3 2 301 300 6
1 5 0 432 427 7 3 1 1 57 30 15 7 5 1 63 56 41 5 10 1 91 61 33 -4 3 2 38 13 29
2 5 0 236 214 7 4 1 1 562 551 8 8 5 1 83 44 71 6 10 1 58 96 57 -3 3 2 454 467 6
3 5 0 798 794 10 5 1 1 150 152 8 9 5 1 165 157 30 7 10 1 194 186 18 -2 3 2 377 389 6
4 5 0 422 422 8 6 1 1 346 347 8 10 5 1 144 80 35 -6 11 1 133 64 37 -1 3 2 461 470 6
5 5 0 388 395 9 7 1 1 231 234 10 -9 6 1 146 133 34 -5 11 1 55 82 54 0 3 2 1264 1240 14
6 5 0 59 74 33 8 1 1 57 55 57 -8 6 1 85 113 64 -4 11 1 248 225 18 1 3 2 515 515 7
7 5 0 248 263 12 9 1 1 177 185 25 -7 6 1 84 79 23 -3 11 1 180 186 21 2 3 2 360 354 6
8 5 0 40 85 39 10 1 1 0 90 1 -6 6 1 280 281 12 -2 11 1 261 248 17 3 3 2 496 517 6
9 5 0 147 97 33 -10 2 1 216 144 36 -5 6 1 90 110 18 -1 11 1 142 123 19 4 3 2 30 26 29
10 5 0 0 49 1 -9 2 1 354 336 20 -4 6 1 59 62 25 0 11 1 0 18 1 5 3 2 352 357 8
0 6 0 1023 1017 17 -8 2 1 62 85 61 -3 6 1 374 366 8 1 11 1 131 127 20 6 3 2 400 397 9
1 6 0 0 42 1 -7 2 1 409 424 12 -2 6 1 386 392 7 2 11 1 249 239 22 7 3 2 160 163 10
2 6 0 303 305 8 -6 2 1 134 140 9 -1 6 1 713 714 9 3 11 1 167 183 26 8 3 2 306 306 13
3 6 0 199 184 8 -5 2 1 62 48 16 0 6 1 353 345 7 4 11 1 221 226 18 9 3 2 62 28 61
4 6 0 74 82 18 -4 2 1 391 378 5 1 6 1 683 683 9 5 11 1 71 76 52 10 3 2 74 71 73
5 6 0 80 84 21 -3 2 1 646 661 7 2 6 1 403 400 8 6 11 1 98 84 50 -10 4 2 162 173 53
6 6 0 418 444 18 -2 2 1 265 260 6 3 6 1 385 373 8 -5 12 1 0 28 1 -9 4 2 132 115 34
7 6 0 0 15 1 -1 2 1 1580 1560 18 4 6 1 112 92 12 -4 12 1 182 133 22 -8 4 2 309 313 20
8 6 0 377 399 13 0 2 1 664 659 11 5 6 1 75 88 24 -3 12 1 129 71 28 -7 4 2 112 44 17
9 6 0 0 34 1 1 2 1 1503 1464 19 6 6 1 280 288 11 -2 12 1 162 140 23 -6 4 2 188 194 12

1 7 0 342 352 9 2 2 1 289 279 9 7 6 1 97 74 21 -1 12 1 0 42
1 -5 4 2 372 374 9
2 7 0 565 567 8 3 2 1 613 615 9 8 6 1 147 126 16 0 12 1 99 93
26 -4 4 2 214 207 7
3 7 0 545 563 8 4 2 1 363 354 7 9 6 1 106 123 105 1 12 1 0 21
1 -3 4 2 374 393 7
4 7 0 248 251 11 5 2 1 90 54 12 -9 7 1 121 37 58 2 12 1 156
131 27 -2 4 2 560 569 8
5 7 0 421 431 11 6 2 1 109 116 11 -8 7 1 143 159 82 3 12 1 138
92 27 -1 4 2 349 347 6
6 7 0 32 32 31 7 2 1 456 452 9 -7 7 1 176 157 16 4 12 1 159
141 25 0 4 2 699 717 8
7 7 0 156 158 17 8 2 1 56 92 56 -6 7 1 305 317 13 5 12 1 0 33
1 1 4 2 375 378 6
8 7 0 141 116 37 9 2 1 332 313 20 -5 7 1 69 79 28 -3 13 1 17 41
16 2 4 2 607 606 7
9 7 0 188 154 29 10 2 1 116 140 71 -4 7 1 407 419 10 -2 13 1 133
93 29 3 4 2 388 401 6
0 8 0 97 71 28 -10 3 1 183 173 40 -3 7 1 210 217 9 -1 13 1 0 30
1 4 4 2 191 196 7
1 8 0 412 415 11 -9 3 1 32 52 31 -2 7 1 186 185 8 0 13 1 70 52
70 5 4 2 364 374 8
2 8 0 508 532 9 -8 3 1 107 88 41 -1 7 1 268 257 9 1 13 1 103 32
35 6 4 2 212 209 9
3 8 0 71 40 21 -7 3 1 29 50 28 0 7 1 0 2 1 2 13 1 111 82 35
7 4 2 0 27 1
4 8 0 169 167 12 -6 3 1 578 600 11 1 7 1 251 237 8 3 13 1 0 29
1 8 4 2 282 273 14
5 8 0 0 47 1 -5 3 1 175 163 7 2 7 1 142 145 11 2 0 2 934 920
13 9 4 2 107 118 46
6 8 0 216 212 14 -4 3 1 967 979 10 3 7 1 195 195 9 3 0 2 43 46
23 10 4 2 182 160 28
7 8 0 306 277 17 -3 3 1 479 463 8 4 7 1 399 391 9 4 0 2 64 45
14 -10 5 2 111 69 83
8 8 0 160 126 18 -2 3 1 1300 1289 15 5 7 1 70 92 28 5 0 2 73
72 14 -9 5 2 130 59 34
1 9 0 0 52 1 -1 3 1 190 183 6 6 7 1 274 294 12 6 0 2 590 606
11 -8 5 2 102 112 45
2 9 0 518 555 12 0 3 1 40 44 36 7 7 1 166 152 17 7 0 2 34 35
34 -7 5 2 317 320 12
3 9 0 77 101 22 1 3 1 196 187 6 8 7 1 156 160 17 8 0 2 196 194
15 -6 5 2 99 90 18
4 9 0 248 258 17 2 3 1 1303 1274 15 9 7 1 95 54 61 9 0 2 59
106 58 -5 5 2 450 449 9

Table 8. Observed and calculated structure factors for $C_{19}H_{19}BrNO_5S$
Page 2

h k l 10Fo 10Fc 10s h k l 10Fo 10Fc 10s h k l 10Fo 10Fc 10s h k l 10Fo 10Fc 10s h k l 10Fo 10Fc 10s

-4 5 2 173 170 8 -6 10 2 48 41 47 4 2 3 435 450 8 -8 7 3 42 28 41 3 12 3 187 183 22
-3 5 2 506 524 7 -5 10 2 250 235 15 5 2 3 264 267 9 -7 7 3 192 187 13 4 12 3 205 160 20
-2 5 2 460 472 6 -4 10 2 0 13 1 6 2 3 268 264 9 -6 7 3 301 307 12 5 12 3 160 100 27
-1 5 2 351 348 7 -3 10 2 283 306 16 7 2 3 231 236 10 -5 7 3 83 87 20 -3 13 3 92 76 47
0 5 2 254 256 6 -2 10 2 292 280 16 8 2 3 187 198 14 -4 7 3 475 465 9 -2 13 3 58 45 57
1 5 2 366 377 9 -1 10 2 170 139 16 9 2 3 290 272 21 -3 7 3 267 275 9 -1 13 3 146 124 25
2 5 2 433 429 7 0 10 2 284 297 13 10 2 3 150 16 48 -2 7 3 536 550 8 0 13 3 87 87 46
3 5 2 484 505 7 1 10 2 171 162 16 -10 3 3 68 56 67 -1 7 3 561 552 8 1 13 3 151 132 33
4 5 2 166 167 9 2 10 2 280 278 13 -9 3 3 123 98 34 0 7 3 79 84 16 2 13 3 48 31 47
5 5 2 430 425 9 3 10 2 299 305 15 -8 3 3 133 106 21 1 7 3 549 542 9 3 13 3 62 69 61
6 5 2 79 110 23 4 10 2 52 15 51 -7 3 3 219 179 16 2 7 3 523 544 9 1 0 4 211 210 6
7 5 2 302 296 11 5 10 2 241 228 15 -6 3 3 325 320 8 3 7 3 288 283 15 2 0 4 604 606 9
8 5 2 125 114 18 6 10 2 0 65 1 -5 3 3 115 108 9 4 7 3 462 478 10 3 0 4 755 742 10
9 5 2 97 63 50 7 10 2 0 57 1 -4 3 3 681 684 7 5 7 3 110 106 17 4 0 4 43 49 28
10 5 2 107 56 72 -6 11 2 73 38 73 -3 3 3 783 746 9 6 7 3 312 308 11 5 0 4 383 399 7
-9 6 2 206 205 25 -5 11 2 208 203 28 -2 3 3 526 517 8 7 7 3 218 203 12 6 0 4 270 267 9
-8 6 2 194 184 24 -4 11 2 0 63 1 -1 3 3 329 298 7 8 7 3 63 30 63 7 0 4 106 125 18
-7 6 2 0 34 1 -3 11 2 215 212 19 0 3 3 336 332 6 9 7 3 136 101 54 8 0 4 101 126 40
-6 6 2 262 240 12 -2 11 2 132 132 26 1 3 3 359 341 6 -8 8 3 87 90 44 9 0 4 114 106 26
-5 6 2 270 271 10 -1 11 2 252 256 17 2 3 3 525 515 6 -7 8 3 195

191 14 10 0 4 152 114 29
-4 6 2 240 244 10 0 11 2 102 93 26 3 3 3 780 762 9 -6 8 3 135 123 17 -10 1 4 242 219 21
-3 6 2 270 258 7 1 11 2 268 261 14 4 3 3 638 642 10 -5 8 3 165 148 14 -9 1 4 112 115 25
-2 6 2 313 307 7 2 11 2 128 126 20 5 3 3 124 122 11 -4 8 3 246 246 10 -8 1 4 313 306 15
-1 6 2 102 97 10 3 11 2 241 218 18 6 3 3 314 306 12 -3 8 3 441 436 10 -7 1 4 238 241 17
0 6 2 723 716 9 4 11 2 80 78 40 7 3 3 132 135 13 -2 8 3 138 142 10 -6 1 4 0 46 1
1 6 2 91 104 13 5 11 2 176 201 18 8 3 3 83 103 25 -1 8 3 385 386 9 -5 1 4 240 235 6
2 6 2 310 308 9 6 11 2 39 47 38 9 3 3 138 124 33 0 8 3 235 245 12 -4 1 4 366 361 6
3 6 2 208 216 9 -5 12 2 78 26 78 10 3 3 87 47 87 1 8 3 372 368 10 -3 1 4 564 548 8
4 6 2 243 234 9 -4 12 2 129 117 33 -10 4 3 51 19 51 2 8 3 100 108 17 -2 1 4 719 724 11
5 6 2 239 246 10 -3 12 2 48 32 48 -9 4 3 242 203 24 3 8 3 411 422 11 -1 1 4 319 291 7
6 6 2 228 254 11 -2 12 2 209 201 20 -8 4 3 206 181 24 4 8 3 264 246 13 0 1 4 598 614 13
7 6 2 0 19 1 -1 12 2 55 37 54 -7 4 3 147 166 26 5 8 3 152 166 17 1 1 4 353 332 6
8 6 2 181 187 15 0 12 2 203 198 18 -6 4 3 164 167 12 6 8 3 153 151 17 2 1 4 733 732 9
9 6 2 188 200 29 1 12 2 42 51 41 -5 4 3 72 63 18 7 8 3 226 196 18 3 1 4 633 616 7
-9 7 2 26 51 26 2 12 2 179 177 21 -4 4 3 245 246 10 8 8 3 99 94 51 4 1 4 345 349 7
-8 7 2 44 110 44 3 12 2 0 15 1 -3 4 3 306 289 7 -8 9 3 120 40 87 5 1 4 240 247 8
-7 7 2 122 81 19 4 12 2 114 111 50 -2 4 3 296 280 6 -7 9 3 68 48 42 6 1 4 46 58 46
-6 7 2 27 70 27 5 12 2 37 46 36 -1 4 3 776 754 9 -6 9 3 85 86 30 7 1 4 257 250 10
-5 7 2 304 295 10 -3 13 2 153 113 26 0 4 3 311 298 6 -5 9 3 18 34 17 8 1 4 292 301 17
-4 7 2 147 147 12 -2 13 2 0 33 1 1 4 3 790 777 9 -4 9 3 157 167 13 9 1 4 95 112 29
-3 7 2 221 221 8 -1 13 2 131 120 28 2 4 3 244 230 11 -3 9 3 210 229 13 10 1 4 169 206 27
-2 7 2 142 148 11 0 13 2 99 35 73 3 4 3 310 288 7 -2 9 3 233 261 16 -10 2 4 92 56 51
-1 7 2 40 35 40 1 13 2 159 113 24 4 4 3 212 217 7 -1 9 3 291

284 12 -9 2 4 72 115 72
0 7 2 49 33 32 2 13 2 0 24 1 5 4 3 0 32 1 0 9 3 264 255 12
-8 2 4 341 324 17
1 7 2 50 46 41 3 13 2 168 114 26 6 4 3 191 175 10 1 9 3 275
305 12 -7 2 4 178 191 13
2 7 2 193 190 16 2 0 3 1483 1439 20 7 4 3 168 180 13 2 9 3 279
294 13 -6 2 4 356 354 11
3 7 2 271 257 11 3 0 3 124 119 7 8 4 3 161 168 16 3 9 3 212
239 12 -5 2 4 532 543 6
4 7 2 146 139 11 4 0 3 826 842 10 9 4 3 252 238 35 4 9 3 165
164 18 -4 2 4 295 280 5
5 7 2 326 308 11 5 0 3 325 326 8 10 4 3 95 16 58 5 9 3 33 49
33 -3 2 4 826 816 10
6 7 2 49 60 49 6 0 3 561 577 9 -9 5 3 155 175 30 6 9 3 119 82
20 -2 2 4 375 379 6
7 7 2 113 111 22 7 0 3 217 212 10 -8 5 3 0 46 1 7 9 3 84 72
60 -1 2 4 1189 1177 15
8 7 2 132 118 18 8 0 3 109 140 19 -7 5 3 269 278 20 8 9 3 73
36 73 0 2 4 1547 1531 19
9 7 2 0 49 1 9 0 3 317 286 15 -6 5 3 340 341 12 -7 10 3 113 90
24 1 2 4 1241 1223 16
-8 8 2 197 157 24 10 0 3 183 163 25 -5 5 3 122 94 13 -6 10 3 164
164 18 2 2 4 365 356 8
-7 8 2 97 103 22 -10 1 3 165 163 45 -4 5 3 489 490 8 -5 10 3 121
96 27 3 2 4 831 815 10
-6 8 2 166 152 15 -9 1 3 266 231 17 -3 5 3 174 182 8 -4 10 3 28
16 27 4 2 4 305 284 8
-5 8 2 100 98 17 -8 1 3 92 107 21 -2 5 3 654 672 8 -3 10 3 0 35
1 5 2 4 487 507 9
-4 8 2 244 270 10 -7 1 3 365 345 11 -1 5 3 397 406 6 -2 10 3 86
80 38 6 2 4 376 369 10
-3 8 2 249 236 9 -6 1 3 430 437 9 0 5 3 763 740 9 -1 10 3 0 9
1 7 2 4 137 144 13
-2 8 2 405 410 9 -5 1 3 366 367 7 1 5 3 382 386 7 0 10 3 169
163 15 8 2 4 358 356 11
-1 8 2 194 187 12 -4 1 3 667 671 9 2 5 3 652 668 8 1 10 3 0 43
1 9 2 4 174 114 37
0 8 2 345 353 11 -3 1 3 501 490 6 3 5 3 227 214 7 2 10 3 114
102 26 10 2 4 0 50 1
1 8 2 210 208 12 -2 1 3 225 231 7 4 5 3 473 480 8 3 10 3 73 14
42 -10 3 4 198 184 25
2 8 2 465 459 13 -1 1 3 659 656 11 5 5 3 111 111 13 4 10 3 0
23 1 -9 3 4 226 222 36
3 8 2 211 208 11 1 1 3 666 679 11 6 5 3 379 389 9 5 10 3 103
107 26 -8 3 4 347 343 17
4 8 2 275 277 11 2 1 3 229 230 6 7 5 3 265 243 11 6 10 3 171

157 18 -7 3 4 190 171 16
5 8 2 51 71 50 3 1 3 541 543 7 8 5 3 99 51 25 7 10 3 115 91
32 -6 3 4 350 346 16
6 8 2 143 142 17 4 1 3 673 678 8 9 5 3 163 159 34 -6 11 3 90
66 42 -5 3 4 575 580 9
7 8 2 109 117 33 5 1 3 360 362 7 -9 6 3 174 186 29 -5 11 3 0 31
1 -4 3 4 199 183 7
8 8 2 234 175 18 6 1 3 373 388 8 -8 6 3 66 71 66 -4 11 3 112 98
30 -3 3 4 873 896 11
-8 9 2 103 117 35 7 1 3 342 338 10 -7 6 3 320 302 12 -3 11 3 0
21 1 -2 3 4 422 413 6
-7 9 2 65 40 49 8 1 3 92 102 23 -6 6 3 242 236 13 -2 11 3 107
90 31 -1 3 4 239 240 6
-6 9 2 155 137 15 9 1 3 211 231 23 -5 6 3 338 331 10 -1 11 3 127
117 32 0 3 4 1420 1340 16
-5 9 2 243 243 14 10 1 3 201 154 25 -4 6 3 306 328 10 0 11 3 274
275 14 1 3 4 219 207 6
-4 9 2 237 232 10 -10 2 3 115 26 34 -3 6 3 206 204 7 1 11 3 136
107 21 2 3 4 405 403 6
-3 9 2 181 191 16 -9 2 3 322 308 20 -2 6 3 455 466 7 2 11 3 47
66 46 3 3 4 898 914 10
-2 9 2 241 239 15 -8 2 3 168 196 17 -1 6 3 428 431 7 3 11 3 0
34 1 4 3 4 201 193 9
-1 9 2 418 438 12 -7 2 3 254 260 11 0 6 3 54 38 17 4 11 3 117
103 26 5 3 4 599 585 9
0 9 2 465 477 12 -6 2 3 228 212 8 1 6 3 446 451 7 5 11 3 103
40 28 6 3 4 376 355 10
1 9 2 399 409 12 -5 2 3 291 285 6 2 6 3 480 479 9 6 11 3 146
94 20 7 3 4 183 174 12
2 9 2 258 271 11 -4 2 3 442 450 6 3 6 3 230 220 10 -5 12 3 94
109 94 8 3 4 343 354 15
3 9 2 197 164 12 -3 2 3 163 147 5 4 6 3 342 335 9 -4 12 3 189
165 22 9 3 4 232 217 27
4 9 2 235 229 15 -2 2 3 423 424 5 5 6 3 311 312 9 -3 12 3 183
168 23 10 3 4 163 162 46
5 9 2 244 233 14 -1 2 3 877 858 15 6 6 3 258 250 11 -2 12 3 128
120 29 -10 4 4 120 67 43
6 9 2 176 144 16 0 2 3 139 119 6 7 6 3 275 289 12 -1 12 3 169
159 27 -9 4 4 106 87 106
7 9 2 82 50 56 1 2 3 938 927 11 8 6 3 65 87 43 0 12 3 120 74
30 -8 4 4 252 248 21
8 9 2 147 111 23 2 2 3 362 359 7 9 6 3 230 191 25 1 12 3 188
180 16 -7 4 4 330 361 19
-7 10 2 80 35 29 3 2 3 213 198 7 -9 7 3 116 87 30 2 12 3 128
125 34 -6 4 4 446 462 11

Table 8. Observed and calculated structure factors for C19H19BrNO5S
Page 3

h k l 10Fo 10Fc 10s h k l 10Fo 10Fc 10s h k l 10Fo 10Fc 10s h k l 10Fo 10Fc 10s h k l 10Fo 10Fc 10s

-5 4 4 585 590 10 7 8 4 146 157 19 3 1 5 686 686 9 -9 6 5 201 184 22 -3 11 5 145 171 24
-4 4 4 184 178 9 8 8 4 113 115 29 4 1 5 379 379 8 -8 6 5 59 64 58 -2 11 5 49 82 48
-3 4 4 672 677 8 -8 9 4 143 137 25 5 1 5 115 122 10 -7 6 5 321 334 17 -1 11 5 366 344 16
-2 4 4 493 491 6 -7 9 4 60 29 59 6 1 5 265 264 10 -6 6 5 196 191 14 0 11 5 119 67 25
-1 4 4 398 402 6 -6 9 4 163 170 15 7 1 5 526 542 11 -5 6 5 171 154 12 1 11 5 335 332 14
0 4 4 611 620 7 -5 9 4 299 290 13 8 1 5 81 34 26 -4 6 5 408 394 14 2 11 5 94 93 29
1 4 4 416 421 6 -4 9 4 81 79 25 9 1 5 251 227 29 -3 6 5 102 87 14 3 11 5 153 149 21
2 4 4 426 432 7 -3 9 4 329 355 12 10 1 5 215 199 34 -2 6 5 241 238 8 4 11 5 58 58 57
3 4 4 665 672 9 -2 9 4 202 178 13 -10 2 5 73 70 73 -1 6 5 455 459 7 5 11 5 111 141 29
4 4 4 172 168 8 -1 9 4 269 265 12 -9 2 5 77 12 47 0 6 5 60 51 16 6 11 5 72 72 51
5 4 4 569 580 8 0 9 4 304 292 19 -8 2 5 202 202 21 1 6 5 446 467 8 -5 12 5 158 47 71
6 4 4 474 470 9 1 9 4 244 262 13 -7 2 5 0 42 1 2 6 5 280 285 8 -4 12 5 66 79 66
7 4 4 379 385 10 2 9 4 152 128 13 -6 2 5 700 731 12 3 6 5 58 67 27 -3 12 5 128 101 32
8 4 4 230 235 14 3 9 4 321 330 11 -5 2 5 253 256 7 4 6 5 369 358 10 -2 12 5 79 81 78
9 4 4 184 87 27 4 9 4 50 62 50 -4 2 5 654 666 7 5 6 5 162 168 12 -1 12 5 122 114 34
10 4 4 75 45 74 5 9 4 279 284 14 -3 2 5 413 412 9 6 6 5 123 148 16 0 12 5 119 92 42
-9 5 4 0 86 1 6 9 4 170 178 17 -2 2 5 649 658 8 7 6 5 343 327 17 1 12 5 109 115 30
-8 5 4 263 245 22 7 9 4 59 31 59 -1 2 5 343 339 7 8 6 5 0 53 1 2 12 5 93 105 43
-7 5 4 153 133 25 8 9 4 179 144 21 0 2 5 1314 1273 16 9 6 5 223 186 17 3 12 5 110 101 53
-6 5 4 216 205 11 -7 10 4 180 112 17 1 2 5 403 401 7 -9 7 5 159

139 25 4 12 5 0 40 1
-5 5 4 385 392 11 -6 10 4 183 170 17 2 2 5 619 626 9 -8 7 5 170 172 24 5 12 5 69 38 69
-4 5 4 247 250 8 -5 10 4 166 148 21 3 2 5 437 429 7 -7 7 5 163 99 20 -3 13 5 80 82 79
-3 5 4 123 113 8 -4 10 4 42 46 41 4 2 5 622 647 9 -6 7 5 57 58 56 -2 13 5 176 150 28
-2 5 4 702 708 9 -3 10 4 271 282 16 5 2 5 289 255 9 -5 7 5 58 44 37 -1 13 5 120 155 33
-1 5 4 268 260 7 -2 10 4 301 324 16 6 2 5 733 747 11 -4 7 5 403 407 9 0 13 5 97 6 36
0 5 4 366 375 6 -1 10 4 235 250 17 7 2 5 88 72 21 -3 7 5 284 283 10 1 13 5 178 152 20
1 5 4 290 291 7 0 10 4 315 304 13 8 2 5 182 208 13 -2 7 5 328 335 11 2 13 5 191 139 27
2 5 4 709 724 9 1 10 4 225 238 13 9 2 5 46 24 46 -1 7 5 250 241 9 3 13 5 96 66 43
3 5 4 193 188 8 2 10 4 360 337 11 -10 3 5 105 63 37 0 7 5 84 85 15 0 0 6 232 248 24
4 5 4 258 263 8 3 10 4 246 251 12 -9 3 5 172 186 24 1 7 5 234 245 10 1 0 6 1624 1563 22
5 5 4 378 391 9 4 10 4 71 46 59 -8 3 5 115 64 23 2 7 5 309 307 10 2 0 6 467 469 8
6 5 4 213 214 11 5 10 4 126 125 22 -7 3 5 287 280 14 3 7 5 309 317 12 3 0 6 1322 1330 16
7 5 4 132 119 16 6 10 4 184 172 22 -6 3 5 0 23 1 4 7 5 434 436 10 4 0 6 356 339 7
8 5 4 284 286 14 7 10 4 158 133 27 -5 3 5 352 361 12 5 7 5 46 44 46 5 0 6 608 632 9
9 5 4 96 84 35 -6 11 4 85 107 85 -4 3 5 142 128 7 6 7 5 67 70 46 6 0 6 59 77 26
-9 6 4 136 145 28 -5 11 4 188 129 29 -3 3 5 406 403 6 7 7 5 111 117 23 7 0 6 81 88 24
-8 6 4 32 60 31 -4 11 4 161 157 32 -2 3 5 253 245 6 8 7 5 174 168 20 8 0 6 0 34 1
-7 6 4 226 225 18 -3 11 4 95 135 95 -1 3 5 827 827 9 9 7 5 142 149 24 9 0 6 116 33 21
-6 6 4 63 44 33 -2 11 4 315 315 17 0 3 5 425 419 5 -8 8 5 83 118 50 10 0 6 0 13 1
-5 6 4 366 370 10 -1 11 4 209 209 19 1 3 5 792 787 10 -7 8 5 86 97 40 -10 1 6 241 219 21
-4 6 4 161 166 10 0 11 4 141 150 23 2 3 5 282 268 7 -6 8 5 280 265 13 -9 1 6 61 42 61
-3 6 4 476 482 11 1 11 4 226 212 15 3 3 5 422 416 7 -5 8 5 174 155 13 -8 1 6 357 352 13
-2 6 4 368 374 7 2 11 4 360 329 17 4 3 5 64 77 19 -4 8 5 286

273 10 -7 1 6 116 133 17
-1 6 4 311 314 7 3 11 4 112 128 26 5 3 5 375 372 8 -3 8 5 94 78 21 -6 1 6 314 295 10
0 6 4 462 462 7 4 11 4 175 154 22 6 3 5 0 14 1 -2 8 5 215 225 12 -5 1 6 201 223 12
1 6 4 311 302 8 5 11 4 138 118 22 7 3 5 269 274 11 -1 8 5 173 153 22 -4 1 6 146 140 8
2 6 4 347 352 10 6 11 4 87 89 36 8 3 5 0 58 1 0 8 5 208 219 12 -3 1 6 634 597 10
3 6 4 466 473 9 -5 12 4 110 116 63 9 3 5 218 198 43 1 8 5 135 134 14 -2 1 6 349 349 8
4 6 4 174 169 11 -4 12 4 116 155 76 -10 4 5 139 121 39 2 8 5 234 241 11 -1 1 6 1134 1080 16
5 6 4 369 380 20 -3 12 4 84 83 59 -9 4 5 76 118 76 3 8 5 75 85 24 0 1 6 372 387 6
6 6 4 93 76 17 -2 12 4 166 162 26 -8 4 5 0 41 1 4 8 5 252 258 11 1 1 6 1152 1098 16
7 6 4 243 231 12 -1 12 4 140 129 24 -7 4 5 171 145 23 5 8 5 143 161 15 2 1 6 348 349 7
8 6 4 110 66 48 0 12 4 83 59 58 -6 4 5 420 424 10 6 8 5 302 290 13 3 1 6 655 622 9
9 6 4 149 141 19 1 12 4 140 114 20 -5 4 5 253 243 10 7 8 5 77 109 37 4 1 6 144 137 8
-9 7 4 114 71 33 2 12 4 139 148 20 -4 4 5 527 536 8 8 8 5 143 126 23 5 1 6 213 207 7
-8 7 4 213 209 19 3 12 4 87 88 51 -3 4 5 267 242 7 -7 9 5 93 95 34 6 1 6 340 342 10
-7 7 4 59 85 59 4 12 4 194 152 21 -2 4 5 419 430 6 -6 9 5 103 66 24 7 1 6 98 136 20
-6 7 4 213 181 12 5 12 4 141 130 23 -1 4 5 91 92 9 -5 9 5 134 142 18 8 1 6 322 325 11
-5 7 4 240 250 11 -3 13 4 109 15 45 0 4 5 204 191 6 -4 9 5 49 53 48 9 1 6 87 66 43
-4 7 4 107 109 14 -2 13 4 64 76 63 1 4 5 91 94 10 -3 9 5 314 308 12 10 1 6 181 219 42
-3 7 4 151 146 11 -1 13 4 71 41 70 2 4 5 409 412 7 -2 9 5 209 201 13 -10 2 6 154 117 34
-2 7 4 357 352 8 0 13 4 123 52 33 3 4 5 277 262 7 -1 9 5 483 473 17 -9 2 6 102 69 24
-1 7 4 152 139 9 1 13 4 102 41 33 4 4 5 526 547 8 0 9 5 54 61 53 -8 2 6 114 97 22
0 7 4 282 267 9 2 13 4 125 99 29 5 4 5 288 269 8 1 9 5 492 497 11 -7 2 6 90 89 29
1 7 4 158 159 11 3 13 4 45 30 45 6 4 5 377 376 10 2 9 5 244 222 12 -6 2 6 228 219 13
2 7 4 390 380 10 1 0 5 1378 1347 19 7 4 5 71 107 42 3 9 5 327

327 11 -5 2 6 377 373 7
3 7 4 123 122 13 2 0 5 21 52 20 8 4 5 68 28 38 4 9 5 11 79
11 -4 2 6 431 429 6
4 7 4 87 95 20 3 0 5 192 180 7 9 4 5 131 115 21 5 9 5 137 148
20 -3 2 6 545 547 7
5 7 4 202 214 12 4 0 5 482 491 7 10 4 5 153 115 47 6 9 5 33 51
32 -2 2 6 401 398 7
6 7 4 148 161 17 5 0 5 327 342 7 -9 5 5 201 193 22 7 9 5 86
105 35 -1 2 6 607 597 8
7 7 4 124 90 21 6 0 5 466 480 10 -8 5 5 43 97 43 -7 10 5 106 26
30 0 2 6 947 912 10
8 7 4 218 198 29 7 0 5 255 249 12 -7 5 5 368 354 16 -6 10 5 209
203 16 1 2 6 611 614 8
9 7 4 69 73 68 8 0 5 0 41 1 -6 5 5 205 198 11 -5 10 5 0 108
1 2 2 6 378 382 7
-8 8 4 115 97 57 9 0 5 104 40 34 -5 5 5 207 219 10 -4 10 5 308
286 16 3 2 6 539 556 8
-7 8 4 213 166 18 10 0 5 104 123 51 -4 5 5 289 287 8 -3 10 5 92
122 61 4 2 6 428 433 8
-6 8 4 98 88 22 -10 1 5 243 213 18 -3 5 5 159 166 8 -2 10 5 159
140 20 5 2 6 361 369 8
-5 8 4 242 251 12 -9 1 5 202 195 30 -2 5 5 327 318 7 -1 10 5 160
134 20 6 2 6 246 225 9
-4 8 4 106 118 17 -8 1 5 0 47 1 -1 5 5 710 736 8 0 10 5 239 240
14 7 2 6 42 39 41
-3 8 4 417 417 10 -7 1 5 518 540 10 0 5 5 243 231 6 1 10 5 124
113 19 8 2 6 101 89 19
-2 8 4 243 246 12 -6 1 5 283 264 10 1 5 5 671 693 9 2 10 5 156
170 14 9 2 6 71 59 70
-1 8 4 306 311 11 -5 1 5 118 137 9 2 5 5 334 322 7 3 10 5 121
109 18 -10 3 6 192 178 23
0 8 4 425 423 11 -4 1 5 429 424 6 3 5 5 108 117 11 4 10 5 305
292 14 -9 3 6 254 225 18
1 8 4 343 338 10 -3 1 5 662 659 8 4 5 5 305 288 8 5 10 5 117
118 23 -8 3 6 176 192 16
2 8 4 281 285 10 -2 1 5 1540 1537 21 5 5 5 238 239 10 6 10 5 216
198 17 -7 3 6 133 128 17
3 8 4 409 410 11 -1 1 5 1311 1265 17 6 5 5 176 187 11 7 10 5 0
23 1 -6 3 6 67 104 32
4 8 4 117 112 20 0 1 5 277 253 7 7 5 5 345 346 10 -6 11 5 55
61 54 -5 3 6 86 89 13
5 8 4 197 219 15 1 1 5 1250 1218 18 8 5 5 108 104 38 -5 11 5 143
131 36 -4 3 6 315 298 6
6 8 4 70 68 41 2 1 5 1511 1482 19 9 5 5 165 161 19 -4 11 5 0
41 1 -3 3 6 436 440 6

Table 8. Observed and calculated structure factors for C19H19BrNO5S
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h k l 10Fo 10Fc 10s h k l 10Fo 10Fc 10s h k l 10Fo 10Fc 10s h k l 10Fo 10Fc 10s h k l 10Fo 10Fc 10s

-2 3 6 458 436 7 8 7 6 344 325 16 -8 1 7 236 222 14 1 5 7 213 224 8 4 10 7 374 379 12
-1 3 6 431 434 6 9 7 6 105 34 31 -7 1 7 260 263 13 2 5 7 238 231 8 5 10 7 147 152 19
0 3 6 770 767 8 -8 8 6 22 28 22 -6 1 7 212 214 11 3 5 7 287 291 8 6 10 7 243 225 16
1 3 6 437 436 6 -7 8 6 117 157 28 -5 1 7 144 119 11 4 5 7 162 162 10 7 10 7 0 13 1
2 3 6 545 528 11 -6 8 6 60 57 60 -4 1 7 28 57 27 5 5 7 332 334 10 -6 11 7 145 119 24
3 3 6 421 417 8 -5 8 6 330 307 13 -3 1 7 313 311 12 6 5 7 275 269 11 -5 11 7 110 139 32
4 3 6 295 280 8 -4 8 6 165 165 15 -2 1 7 180 166 8 7 5 7 333 320 11 -4 11 7 115 139 44
5 3 6 82 78 15 -3 8 6 440 450 10 -1 1 7 1230 1214 15 8 5 7 148 112 18 -3 11 7 127 144 33
6 3 6 150 150 13 -2 8 6 253 257 12 0 1 7 412 451 6 9 5 7 152 129 20 -2 11 7 77 107 56
7 3 6 135 142 15 -1 8 6 91 92 23 1 1 7 1236 1226 17 -9 6 7 118 86 32 -1 11 7 284 271 17
8 3 6 225 190 16 0 8 6 90 87 20 2 1 7 178 165 8 -8 6 7 67 111 67 0 11 7 136 143 24
9 3 6 206 231 37 1 8 6 63 56 29 3 1 7 293 286 8 -7 6 7 88 75 35 1 11 7 262 272 16
-10 4 6 60 39 59 2 8 6 262 274 11 4 1 7 55 59 17 -6 6 7 230 210 16 2 11 7 44 101 44
-9 4 6 109 85 46 3 8 6 422 443 11 5 1 7 138 147 11 -5 6 7 0 19 1 3 11 7 134 143 18
-8 4 6 102 40 32 4 8 6 175 185 13 6 1 7 205 197 11 -4 6 7 377 389 11 4 11 7 138 137 22
-7 4 6 286 278 16 5 8 6 304 295 11 7 1 7 234 227 15 -3 6 7 230 228 9 5 11 7 166 146 19
-6 4 6 212 222 13 6 8 6 94 67 27 8 1 7 204 205 14 -2 6 7 238 230 11 6 11 7 123 119 23
-5 4 6 413 398 9 7 8 6 141 123 19 9 1 7 274 277 16 -1 6 7 391 379 7 -4 12 7 0 81 1
-4 4 6 251 243 10 8 8 6 106 39 30 10 1 7 147 85 27 0 6 7 31 16 30 -3 12 7 247 231 25
-3 4 6 416 433 7 -7 9 6 80 49 57 -10 2 7 178 147 21 1 6 7 392

389 8 -2 12 7 27 37 27
-2 4 6 330 319 8 -6 9 6 42 38 41 -9 2 7 79 70 38 2 6 7 254 239
8 -1 12 7 82 86 53
-1 4 6 325 315 6 -5 9 6 150 154 17 -8 2 7 140 155 19 3 6 7 231
235 10 0 12 7 108 26 31
0 4 6 777 759 9 -4 9 6 116 97 31 -7 2 7 0 33 1 4 6 7 294 302
11 1 12 7 105 91 27
1 4 6 367 357 7 -3 9 6 243 253 14 -6 2 7 349 347 12 5 6 7 82 35
22 2 12 7 0 11 1
2 4 6 325 320 7 -2 9 6 117 100 19 -5 2 7 336 322 10 6 6 7 216
227 12 3 12 7 252 231 15
3 4 6 409 417 8 -1 9 6 225 216 16 -4 2 7 937 948 11 7 6 7 48 72
47 4 12 7 111 93 28
4 4 6 214 226 9 0 9 6 116 117 17 -3 2 7 716 716 9 8 6 7 114
109 23 -2 13 7 102 38 73
5 4 6 433 443 9 1 9 6 210 214 12 -2 2 7 749 744 10 9 6 7 57 84
57 -1 13 7 0 84 1
6 4 6 219 206 10 2 9 6 108 110 18 -1 2 7 162 147 5 -8 7 7 101
60 35 0 13 7 0 24 1
7 4 6 285 272 11 3 9 6 241 238 12 0 2 7 486 469 6 -7 7 7 137
133 41 1 13 7 55 90 55
8 4 6 75 61 30 4 9 6 36 81 36 1 2 7 159 149 7 -6 7 7 97 105
32 2 13 7 86 30 42
9 4 6 34 80 34 5 9 6 151 149 18 2 2 7 786 801 10 -5 7 7 0 68
1 0 0 8 145 128 9
10 4 6 103 35 103 6 9 6 90 29 29 3 2 7 690 698 10 -4 7 7 73 96
28 1 0 8 647 642 9
-9 5 6 59 11 58 7 9 6 17 34 17 4 2 7 887 908 13 -3 7 7 213 209
10 2 0 8 383 367 7
-8 5 6 276 265 20 -7 10 6 143 119 29 5 2 7 290 301 9 -2 7 7 135
127 12 3 0 8 810 824 11
-7 5 6 79 119 78 -6 10 6 77 82 57 6 2 7 356 352 10 -1 7 7 83 87
17 4 0 8 125 114 10
-6 5 6 173 181 18 -5 10 6 70 70 70 7 2 7 24 35 24 0 7 7 118 111
12 5 0 8 427 445 9
-5 5 6 246 238 10 -4 10 6 78 122 55 8 2 7 173 144 18 1 7 7 144
150 10 6 0 8 107 85 24
-4 5 6 158 137 9 -3 10 6 85 74 36 9 2 7 90 64 32 2 7 7 133 132
14 7 0 8 67 28 38
-3 5 6 134 158 10 -2 10 6 0 71 1 -10 3 7 159 119 25 3 7 7 226
231 11 8 0 8 117 100 20
-2 5 6 873 882 11 -1 10 6 118 113 26 -9 3 7 257 267 15 4 7 7 72
100 27 9 0 8 299 272 13
-1 5 6 184 173 7 0 10 6 0 67 1 -8 3 7 186 196 19 5 7 7 0 51
1 10 0 8 35 30 35
0 5 6 847 860 9 1 10 6 106 91 23 -7 3 7 486 498 13 6 7 7 94 85

22 -10 1 8 134 130 42
1 5 6 183 176 8 2 10 6 88 81 24 -6 3 7 90 119 30 7 7 7 118 94 21 -9 1 8 130 143 21
2 5 6 911 929 11 3 10 6 104 67 20 -5 3 7 460 436 8 8 7 7 73 55 42 -8 1 8 441 437 17
3 5 6 149 143 9 4 10 6 111 113 20 -4 3 7 115 117 9 -8 8 7 173 154 22 -7 1 8 245 253 13
4 5 6 171 151 9 5 10 6 92 63 30 -3 3 7 365 364 7 -7 8 7 0 12 1 -6 1 8 486 502 10
5 5 6 240 251 11 6 10 6 81 82 40 -2 3 7 218 214 7 -6 8 7 174 187 17 -5 1 8 296 311 9
6 5 6 137 148 14 7 10 6 136 108 21 -1 3 7 1710 1679 19 -5 8 7 138 149 19 -4 1 8 547 538 9
7 5 6 132 108 16 -6 11 6 57 8 56 0 3 7 168 159 6 -4 8 7 274 273 12 -3 1 8 321 331 8
8 5 6 278 267 13 -5 11 6 129 103 51 1 3 7 1715 1672 18 -3 8 7 246 260 10 -2 1 8 689 703 9
9 5 6 89 10 29 -4 11 6 165 185 63 2 3 7 224 218 7 -2 8 7 275 269 12 -1 1 8 258 241 6
-9 6 6 160 120 24 -3 11 6 83 67 48 3 3 7 399 390 8 -1 8 7 225 210 12 0 1 8 726 736 8
-8 6 6 56 56 55 -2 11 6 223 192 20 4 3 7 123 120 10 0 8 7 54 85 47 1 1 8 239 230 8
-7 6 6 217 190 17 -1 11 6 120 105 46 5 3 7 417 420 11 1 8 7 208 201 11 2 1 8 685 694 11
-6 6 6 0 17 1 0 11 6 81 78 45 6 3 7 116 123 17 2 8 7 289 290 10 3 1 8 341 345 9
-5 6 6 476 476 10 1 11 6 112 98 23 7 3 7 505 497 13 3 8 7 235 243 11 4 1 8 553 540 8
-4 6 6 184 172 9 2 11 6 242 221 14 8 3 7 161 173 16 4 8 7 217 229 12 5 1 8 331 334 10
-3 6 6 705 731 10 3 11 6 100 63 22 -10 4 7 193 186 22 5 8 7 129 138 16 6 1 8 485 490 15
-2 6 6 54 58 26 4 11 6 189 187 21 -9 4 7 73 45 73 6 8 7 197 219 16 7 1 8 266 274 12
-1 6 6 346 331 7 5 11 6 129 111 23 -8 4 7 100 74 34 7 8 7 0 15 1 8 1 8 446 448 13
0 6 6 425 423 7 6 11 6 117 24 25 -7 4 7 92 95 27 8 8 7 170 158 22 9 1 8 166 140 19
1 6 6 321 323 8 -4 12 6 119 56 47 -6 4 7 314 331 12 -7 9 7 245 236 18 10 1 8 161 137 26
2 6 6 62 72 20 -3 12 6 268 248 18 -5 4 7 299 293 8 -6 9 7 74 41 44 -10 2 8 79 74 62
3 6 6 701 732 11 -2 12 6 74 74 73 -4 4 7 763 744 10 -5 9 7 162 175 23 -9 2 8 122 115 22
4 6 6 137 157 13 -1 12 6 181 154 22 -3 4 7 402 399 8 -4 9 7 0

27 1 -8 2 8 187 207 16
5 6 6 501 502 12 0 12 6 121 131 29 -2 4 7 513 517 8 -3 9 7 219 222 13 -7 2 8 160 171 17
6 6 6 0 5 1 1 12 6 142 146 24 -1 4 7 324 317 8 -2 9 7 34 52 34 -6 2 8 343 340 12
7 6 6 212 204 15 2 12 6 78 79 36 0 4 7 137 121 7 -1 9 7 523 511 18 -5 2 8 560 577 11
8 6 6 108 50 22 3 12 6 233 243 19 1 4 7 322 317 7 0 9 7 76 31 27 -4 2 8 470 475 7
9 6 6 141 118 23 4 12 6 32 47 32 2 4 7 495 505 8 1 9 7 481 493 13 -3 2 8 530 524 8
-9 7 6 0 45 1 -2 13 6 118 68 33 3 4 7 396 403 8 2 9 7 0 55 1 -2 2 8 764 766 10
-8 7 6 313 333 18 -1 13 6 112 63 35 4 4 7 725 721 12 3 9 7 214 226 12 -1 2 8 320 321 5
-7 7 6 79 45 44 0 13 6 98 108 38 5 4 7 306 293 11 4 9 7 24 34 24 0 2 8 234 234 6
-6 7 6 291 284 13 1 13 6 81 62 49 6 4 7 368 360 11 5 9 7 200 181 13 1 2 8 326 321 8
-5 7 6 217 224 11 2 13 6 0 64 1 7 4 7 0 90 1 6 9 7 49 26 48 2 2 8 756 752 10
-4 7 6 114 113 18 1 0 7 327 334 8 8 4 7 91 84 23 7 9 7 273 252 18 3 2 8 522 512 8
-3 7 6 87 59 16 2 0 7 553 531 9 9 4 7 85 50 46 -7 10 7 60 11 60 4 2 8 491 503 8
-2 7 6 643 650 10 3 0 7 345 326 7 -9 5 7 119 109 59 -6 10 7 248 223 45 5 2 8 618 622 9
-1 7 6 144 125 10 4 0 7 718 722 10 -8 5 7 98 109 33 -5 10 7 139 151 43 6 2 8 348 341 10
0 7 6 730 729 10 5 0 7 121 124 11 -7 5 7 279 283 16 -4 10 7 357 370 16 7 2 8 201 200 13
1 7 6 123 125 11 6 0 7 403 405 11 -6 5 7 246 244 15 -3 10 7 276 261 16 8 2 8 230 206 15
2 7 6 617 630 10 7 0 7 234 233 13 -5 5 7 348 333 10 -2 10 7 312 298 15 9 2 8 116 101 26
3 7 6 61 47 32 8 0 7 142 149 17 -4 5 7 155 154 11 -1 10 7 157 183 20 -10 3 8 114 121 26
4 7 6 116 106 16 9 0 7 0 48 1 -3 5 7 265 277 9 0 10 7 0 10 1 -9 3 8 58 22 57
5 7 6 193 217 12 10 0 7 105 73 105 -2 5 7 250 237 8 1 10 7 185 190 15 -8 3 8 242 231 17
6 7 6 330 316 11 -10 1 7 91 85 36 -1 5 7 264 268 6 2 10 7 276 272 12 -7 3 8 148 127 17
7 7 6 68 62 44 -9 1 7 272 265 14 0 5 7 285 297 6 3 10 7 267 273 14 -6 3 8 203 196 12

Table 8. Observed and calculated structure factors for $C_{19}H_{19}BrNO_5S$
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h k l 10Fo 10Fc 10s h k l 10Fo 10Fc 10s h k l 10Fo 10Fc 10s h k l 10Fo 10Fc 10s h k l 10Fo 10Fc 10s

-5 3 8 155 151 14 8 7 8 232 232 16 -3 1 9 738 733 10 5 5 9 290 286 10 -3 11 9 289 256 43
-4 3 8 113 117 9 -8 8 8 125 117 28 -2 1 9 580 582 8 6 5 9 111 120 25 -2 11 9 21 52 21
-3 3 8 347 340 7 -7 8 8 0 44 1 -1 1 9 548 544 7 7 5 9 249 216 12 -1 11 9 223 227 18
-2 3 8 481 476 7 -6 8 8 80 87 45 0 1 9 279 282 6 8 5 9 106 115 21 0 11 9 127 111 25
-1 3 8 450 460 6 -5 8 8 276 253 16 1 1 9 551 547 9 9 5 9 137 129 25 1 11 9 199 230 24
0 3 8 128 125 7 -4 8 8 123 126 18 2 1 9 529 556 10 -9 6 9 130 173 40 2 11 9 100 73 24
1 3 8 448 455 7 -3 8 8 393 396 10 3 1 9 708 704 12 -8 6 9 57 34 56 3 11 9 246 261 13
2 3 8 462 455 8 -2 8 8 121 126 18 4 1 9 377 368 9 -7 6 9 158 198 22 4 11 9 49 52 48
3 3 8 337 336 8 -1 8 8 181 208 14 5 1 9 296 293 12 -6 6 9 126 93 23 5 11 9 72 50 72
4 3 8 116 108 11 0 8 8 47 23 47 6 1 9 136 139 15 -5 6 9 155 158 15 -4 12 9 203 191 31
5 3 8 194 178 12 1 8 8 209 207 11 7 1 9 276 283 13 -4 6 9 155 158 14 -3 12 9 129 111 43
6 3 8 211 186 17 2 8 8 157 142 19 8 1 9 70 35 37 -3 6 9 144 148 11 -2 12 9 110 146 34
7 3 8 156 164 15 3 8 8 392 396 11 9 1 9 214 217 18 -2 6 9 0 25 1 -1 12 9 207 192 20
8 3 8 254 256 14 4 8 8 145 144 15 10 1 9 72 107 72 -1 6 9 494 501 8 0 12 9 201 178 20
9 3 8 93 35 43 5 8 8 270 275 12 -10 2 9 126 118 24 0 6 9 246 252 8 1 12 9 208 203 20
-9 4 8 110 44 45 6 8 8 109 93 20 -9 2 9 71 109 71 1 6 9 512 503 8 2 12 9 0 138 1
-8 4 8 174 163 17 7 8 8 59 63 58 -8 2 9 151 154 19 2 6 9 59 73 22 3 12 9 126 109 23
-7 4 8 151 142 17 8 8 8 143 131 28 -7 2 9 120 108 20 3 6 9 146 145 12 4 12 9 215 192 17
-6 4 8 151 149 17 -7 9 8 169 154 21 -6 2 9 337 319 11 4 6 9 57 102 56 -2 13 9 29 109 29
-5 4 8 611 632 19 -6 9 8 74 79 55 -5 2 9 222 224 11 5 6 9 152

169 14 -1 13 9 122 92 32
-4 4 8 145 122 10 -5 9 8 266 224 14 -4 2 9 569 586 10 6 6 9 60 84 60 0 13 9 0 28 1
-3 4 8 485 489 7 -4 9 8 54 63 54 -3 2 9 524 541 8 7 6 9 213 197 13 1 13 9 126 101 27
-2 4 8 430 427 8 -3 9 8 101 111 21 -2 2 9 720 707 10 8 6 9 70 34 50 2 13 9 122 121 30
-1 4 8 293 291 6 -2 9 8 198 211 14 -1 2 9 198 195 6 9 6 9 159 171 24 0 0 10 1132 1097 18
0 4 8 92 105 12 -1 9 8 188 193 18 0 2 9 127 131 8 -8 7 9 0 12 1 1 0 10 370 367 6
1 4 8 273 260 6 0 9 8 279 303 15 1 2 9 206 210 7 -7 7 9 236 234 20 2 0 10 311 295 11
2 4 8 394 399 7 1 9 8 190 187 13 2 2 9 735 742 10 -6 7 9 238 245 17 3 0 10 415 416 8
3 4 8 491 508 8 2 9 8 234 241 12 3 2 9 542 535 8 -5 7 9 135 155 18 4 0 10 269 275 8
4 4 8 153 145 13 3 9 8 91 98 22 4 2 9 534 545 9 -4 7 9 533 558 17 5 0 10 310 303 11
5 4 8 551 575 11 4 9 8 0 52 1 5 2 9 213 216 10 -3 7 9 20 62 19 6 0 10 118 155 17
6 4 8 143 151 15 5 9 8 244 232 13 6 2 9 310 301 10 -2 7 9 282 273 9 7 0 10 86 62 37
7 4 8 127 124 23 6 9 8 44 48 43 7 2 9 101 118 28 -1 7 9 405 399 11 8 0 10 109 107 22
8 4 8 152 152 27 7 9 8 182 160 21 8 2 9 156 157 19 0 7 9 115 101 12 9 0 10 143 112 20
9 4 8 0 32 1 -6 10 8 144 155 30 9 2 9 108 104 29 1 7 9 409 418 9 10 0 10 159 109 21
-9 5 8 67 75 67 -5 10 8 132 133 26 10 2 9 174 114 40 2 7 9 295 279 10 -10 1 10 123 91 24
-8 5 8 333 335 17 -4 10 8 96 91 32 -10 3 9 195 166 17 3 7 9 63 67 30 -9 1 10 215 232 16
-7 5 8 175 193 19 -3 10 8 21 73 21 -9 3 9 158 135 19 4 7 9 552 570 12 -8 1 10 278 283 14
-6 5 8 175 157 22 -2 10 8 252 239 16 -8 3 9 152 146 23 5 7 9 184 180 13 -7 1 10 295 291 13
-5 5 8 243 236 18 -1 10 8 62 17 61 -7 3 9 377 360 13 6 7 9 254 235 13 -6 1 10 158 163 15
-4 5 8 328 316 11 0 10 8 368 362 15 -6 3 9 305 312 12 7 7 9 221 224 13 -5 1 10 380 391 9
-3 5 8 306 295 8 1 10 8 0 11 1 -5 3 9 200 206 12 8 7 9 0 31 1 -4 1 10 204 195 9
-2 5 8 484 505 8 2 10 8 212 221 14 -4 3 9 159 159 10 -8 8 9 109 78 30 -3 1 10 328 311 9
-1 5 8 243 225 7 3 10 8 104 70 22 -3 3 9 173 167 7 -7 8 9 121

142 28 -2 1 10 121 130 8
0 5 8 945 951 10 4 10 8 87 72 26 -2 3 9 301 299 7 -6 8 9 266 272 17 -1 1 10 280 262 6
1 5 8 255 239 6 5 10 8 126 90 21 -1 3 9 761 748 8 -5 8 9 135 141 19 0 1 10 224 224 6
2 5 8 468 489 8 6 10 8 181 161 18 0 3 9 251 220 6 -4 8 9 343 345 12 1 1 10 282 264 6
3 5 8 300 307 8 -5 11 8 94 90 93 1 3 9 741 741 10 -3 8 9 128 120 17 2 1 10 199 194 11
4 5 8 308 309 9 -4 11 8 148 89 31 2 3 9 328 324 7 -2 8 9 215 203 12 3 1 10 400 380 9
5 5 8 222 226 11 -3 11 8 150 139 32 3 3 9 121 130 11 -1 8 9 239 225 12 4 1 10 195 195 11
6 5 8 151 146 14 -2 11 8 26 32 25 4 3 9 180 174 9 0 8 9 110 99 16 5 1 10 362 371 11
7 5 8 194 192 13 -1 11 8 0 43 1 5 3 9 243 244 11 1 8 9 234 227 12 6 1 10 160 153 13
8 5 8 327 329 12 0 11 8 243 227 18 6 3 9 257 276 12 2 8 9 234 236 11 7 1 10 281 291 18
9 5 8 97 74 32 1 11 8 59 40 59 7 3 9 356 362 13 3 8 9 68 94 35 8 1 10 347 310 15
-9 6 8 100 110 39 2 11 8 38 13 38 8 3 9 135 154 20 4 8 9 302 320 12 9 1 10 236 226 17
-8 6 8 98 98 38 3 11 8 141 134 33 9 3 9 141 128 61 5 8 9 166 143 14 10 1 10 153 117 22
-7 6 8 110 97 30 4 11 8 44 87 44 -9 4 9 139 150 31 6 8 9 265 248 17 -10 2 10 177 149 19
-6 6 8 14 46 13 5 11 8 137 71 21 -8 4 9 56 63 56 7 8 9 130 129 22 -9 2 10 148 101 20
-5 6 8 545 543 13 -4 12 8 87 48 86 -7 4 9 108 105 23 8 8 9 36 77 36 -8 2 10 282 256 22
-4 6 8 280 264 11 -3 12 8 147 114 35 -6 4 9 406 405 13 -7 9 9 209 165 19 -7 2 10 51 83 51
-3 6 8 799 824 11 -2 12 8 72 109 72 -5 4 9 286 306 15 -6 9 9 129 98 25 -6 2 10 206 183 11
-2 6 8 130 126 11 -1 12 8 134 104 28 -4 4 9 288 291 9 -5 9 9 94 97 35 -5 2 10 389 377 10
-1 6 8 414 416 7 0 12 8 80 90 61 -3 4 9 166 153 9 -4 9 9 0 26 1 -4 2 10 412 401 10
0 6 8 128 105 11 1 12 8 127 122 25 -2 4 9 352 367 8 -3 9 9 0 7 1 -3 2 10 505 504 9
1 6 8 428 438 8 2 12 8 113 114 29 -1 4 9 62 68 13 -2 9 9 55 63 55 -2 2 10 243 249 7
2 6 8 99 115 13 3 12 8 73 102 42 0 4 9 226 205 6 -1 9 9 217 215 16 -1 2 10 558 548 6
3 6 8 798 833 10 4 12 8 29 34 28 1 4 9 0 30 1 0 9 9 292 316

13 0 2 10 194 197 7
4 6 8 260 256 11 -2 13 8 117 103 36 2 4 9 354 361 7 1 9 9 181 179 13 1 2 10 498 509 10
5 6 8 533 534 14 -1 13 8 105 101 41 3 4 9 158 143 11 2 9 9 92 88 23 2 2 10 182 184 9
6 6 8 29 53 28 0 13 8 139 120 28 4 4 9 279 284 11 3 9 9 53 20 53 3 2 10 459 451 9
7 6 8 136 101 16 1 13 8 84 91 61 5 4 9 281 289 11 4 9 9 79 55 29 4 2 10 391 380 9
8 6 8 100 107 29 2 13 8 126 108 29 6 4 9 473 441 20 5 9 9 74 96 35 5 2 10 428 418 9
9 6 8 95 108 38 1 0 9 460 469 7 7 4 9 140 124 21 6 9 9 106 85 28 6 2 10 193 182 12
-8 7 8 242 223 19 2 0 9 772 745 10 8 4 9 61 59 60 7 9 9 162 164 19 7 2 10 118 97 23
-7 7 8 119 177 28 3 0 9 506 495 8 9 4 9 151 160 20 -6 10 9 155 133 27 8 2 10 234 228 17
-6 7 8 228 209 17 4 0 9 519 516 8 -9 5 9 132 112 45 -5 10 9 187 153 23 9 2 10 95 86 38
-5 7 8 79 58 31 5 0 9 161 146 12 -8 5 9 127 111 27 -4 10 9 160 140 21 10 2 10 148 157 44
-4 7 8 154 135 14 6 0 9 234 238 12 -7 5 9 200 182 18 -3 10 9 0 13 1 -9 3 10 0 23 1
-3 7 8 212 199 10 7 0 9 316 339 13 -6 5 9 152 167 19 -2 10 9 206 167 17 -8 3 10 311 304 14
-2 7 8 370 357 16 8 0 9 0 65 1 -5 5 9 267 276 15 -1 10 9 125 119 29 -7 3 10 170 175 20
-1 7 8 209 211 11 9 0 9 171 170 17 -4 5 9 351 343 11 0 10 9 0 30 1 -6 3 10 207 209 13
0 7 8 608 612 10 10 0 9 116 56 38 -3 5 9 402 404 11 1 10 9 114 147 28 -5 3 10 428 438 15
1 7 8 203 199 9 -10 1 9 124 106 23 -2 5 9 324 312 8 2 10 9 146 166 16 -4 3 10 381 383 11
2 7 8 370 358 10 -9 1 9 236 236 15 -1 5 9 502 517 7 3 10 9 20 17 20 -3 3 10 473 492 8
3 7 8 182 189 12 -8 1 9 60 47 60 0 5 9 321 324 6 4 10 9 143 150 18 -2 3 10 728 728 8
4 7 8 144 131 14 -7 1 9 300 312 13 1 5 9 550 560 7 5 10 9 120 139 31 -1 3 10 618 600 7
5 7 8 79 83 27 -6 1 9 178 185 13 2 5 9 294 302 8 6 10 9 145 131 21 0 3 10 322 332 6
6 7 8 198 213 14 -5 1 9 242 249 10 3 5 9 429 441 8 -5 11 9 66 60 65 1 3 10 600 596 9
7 7 8 180 184 17 -4 1 9 351 363 9 4 5 9 323 319 11 -4 11 9 0 44 1 2 3 10 746 749 10

Table 8. Observed and calculated structure factors for $C_{19}H_{19}BrNO_5S$
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h k l 10Fo 10Fc 10s h k l 10Fo 10Fc 10s h k l 10Fo 10Fc 10s h k l 10Fo 10Fc 10s h k l 10Fo 10Fc 10s

3 3 10 460 467 8 -1 8 10 262 269 12 7 1 11 343 354 13 -3 6 11 305 310 11 1 12 11 101 82 36
4 3 10 362 376 11 0 8 10 238 242 11 8 1 11 171 169 20 -2 6 11 242 259 9 2 12 11 103 124 27
5 3 10 479 470 12 1 8 10 250 260 11 9 1 11 228 219 18 -1 6 11 476 470 8 3 12 11 85 59 46
6 3 10 183 170 15 2 8 10 206 190 12 10 1 11 61 32 60 0 6 11 80 62 15 0 0 12 573 557 11
7 3 10 182 178 15 3 8 10 145 122 15 -10 2 11 158 112 19 1 6 11 442 438 9 1 0 12 563 536 7
8 3 10 302 292 16 4 8 10 22 26 21 -9 2 11 184 194 19 2 6 11 270 273 9 2 0 12 1069 1048 14
9 3 10 70 15 69 5 8 10 249 268 12 -8 2 11 127 114 22 3 6 11 285 301 9 3 0 12 72 100 24
-9 4 10 163 111 20 6 8 10 0 21 1 -7 2 11 215 231 15 4 6 11 547 557 23 4 0 12 153 153 12
-8 4 10 206 209 19 7 8 10 139 157 27 -6 2 11 160 175 16 5 6 11 201 213 14 5 0 12 138 160 15
-7 4 10 76 70 38 8 8 10 90 34 36 -5 2 11 441 448 10 6 6 11 137 139 16 6 0 12 357 360 12
-6 4 10 240 252 13 -7 9 10 138 127 25 -4 2 11 362 363 10 7 6 11 177 182 15 7 0 12 47 22 46
-5 4 10 383 388 15 -6 9 10 143 166 24 -3 2 11 678 687 10 8 6 11 77 51 32 8 0 12 296 293 14
-4 4 10 311 314 13 -5 9 10 224 192 15 -2 2 11 470 476 7 9 6 11 195 170 17 9 0 12 87 29 42
-3 4 10 563 569 9 -4 9 10 119 76 25 -1 2 11 528 537 6 -8 7 11 142 143 88 10 0 12 158 184 23
-2 4 10 497 494 8 -3 9 10 288 288 15 0 2 11 23 11 23 -7 7 11 234 229 19 -10 1 12 16 26 16
-1 4 10 406 406 6 -2 9 10 277 266 12 1 2 11 511 509 8 -6 7 11 265 254 21 -9 1 12 126 75 24
0 4 10 620 622 7 -1 9 10 72 42 34 2 2 11 501 517 9 -5 7 11 282 298 15 -8 1 12 116 112 23
1 4 10 421 417 6 0 9 10 266 291 13 3 2 11 712 716 11 -4 7 11 291 293 12 -7 1 12 291 297 13
2 4 10 499 488 7 1 9 10 75 70 27 4 2 11 423 404 10 -3 7 11 138 124 19 -6 1 12 103 93 22
3 4 10 564 570 10 2 9 10 253 262 12 5 2 11 427 435 11 -2 7 11 586

605 13 -5 1 12 562 605 11
4 4 10 337 322 11 3 9 10 291 288 12 6 2 11 181 155 13 -1 7 11 336 343 10 -4 1 12 210 214 10
5 4 10 358 349 17 4 9 10 46 73 46 7 2 11 255 264 15 0 7 11 307 322 10 -3 1 12 477 474 8
6 4 10 231 237 13 5 9 10 194 186 25 8 2 11 87 116 36 1 7 11 357 344 9 -2 1 12 81 84 11
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8 4 10 188 192 23 7 9 10 115 106 27 10 2 11 129 125 74 3 7 11 137 135 15 0 1 12 262 253 7
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-8 5 10 214 213 25 -4 10 10 145 151 29 -7 3 11 186 170 16 6 7 11 283 272 14 3 1 12 493 496 10
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-6 5 10 258 247 16 -2 10 10 184 181 19 -5 3 11 255 260 12 8 7 11 118 150 26 5 1 12 547 580 11
-5 5 10 303 297 14 -1 10 10 17 68 17 -4 3 11 481 496 11 -7 8 11 121 122 29 6 1 12 85 84 23
-4 5 10 248 248 11 0 10 10 382 355 20 -3 3 11 227 220 8 -6 8 11 124 120 25 7 1 12 279 265 13
-3 5 10 219 227 14 1 10 10 53 63 52 -2 3 11 231 227 6 -5 8 11 218 203 19 8 1 12 0 80 1
-2 5 10 234 237 9 2 10 10 179 171 14 -1 3 11 286 275 6 -4 8 11 190 180 14 9 1 12 104 75 34
-1 5 10 141 151 7 3 10 10 238 219 13 0 3 11 90 73 11 -3 8 11 180 206 17 10 1 12 44 28 44
0 5 10 435 440 7 4 10 10 160 156 15 1 3 11 249 228 9 -2 8 11 176 170 16 -9 2 12 118 60 27
1 5 10 127 127 10 5 10 10 226 205 14 2 3 11 222 224 9 -1 8 11 319 306 12 -8 2 12 288 274 15
2 5 10 225 221 9 6 10 10 248 184 16 3 3 11 223 218 9 0 8 11 96 77 18 -7 2 12 133 141 21
3 5 10 175 182 10 -5 11 10 226 213 38 4 3 11 511 512 9 1 8 11 305 306 11 -6 2 12 346 348 13
4 5 10 242 251 9 -4 11 10 135 92 32 5 3 11 281 291 12 2 8 11 170 163 12 -5 2 12 114 105 14
5 5 10 350 351 11 -3 11 10 256 209 23 6 3 11 95 122 25 3 8 11 221 230 12 -4 2 12 315 329 9
6 5 10 252 252 12 -2 11 10 125 114 34 7 3 11 199 182 17 4 8 11 160 157 15 -3 2 12 357 377 9
7 5 10 165 160 15 -1 11 10 165 159 21 8 3 11 89 104 38 5 8 11 201

205 14 -2 2 12 565 577 8
8 5 10 209 209 14 0 11 10 249 235 32 9 3 11 96 85 47 6 8 11 87 112 27 -1 2 12 360 367 7
9 5 10 82 79 51 1 11 10 143 143 38 -9 4 11 242 236 17 7 8 11 154 132 16 0 2 12 728 724 9
-9 6 10 28 49 28 2 11 10 87 95 32 -8 4 11 64 33 64 -7 9 11 115 46 29 1 2 12 370 361 6
-8 6 10 63 51 63 3 11 10 231 219 13 -7 4 11 235 240 18 -6 9 11 219 209 18 2 2 12 570 560 10
-7 6 10 82 28 41 4 11 10 85 93 30 -6 4 11 84 60 26 -5 9 11 76 71 75 3 2 12 369 370 10
-6 6 10 75 57 43 5 11 10 237 209 17 -5 4 11 108 109 19 -4 9 11 177 173 20 4 2 12 311 309 10
-5 6 10 120 142 23 -4 12 10 98 54 71 -4 4 11 182 180 15 -3 9 11 0 3 1 5 2 12 79 79 22
-4 6 10 204 189 12 -3 12 10 105 46 85 -3 4 11 349 368 9 -2 9 11 225 239 14 6 2 12 352 348 14
-3 6 10 444 451 11 -2 12 10 0 75 1 -2 4 11 135 121 8 -1 9 11 131 121 18 7 2 12 132 138 22
-2 6 10 133 129 11 -1 12 10 150 132 24 -1 4 11 158 162 7 0 9 11 217 227 14 8 2 12 237 261 17
-1 6 10 317 309 8 0 12 10 168 122 23 0 4 11 0 7 1 1 9 11 150 149 17 9 2 12 125 88 37
0 6 10 294 300 8 1 12 10 183 142 29 1 4 11 220 216 7 2 9 11 223 231 12 -9 3 12 0 27 1
1 6 10 326 325 8 2 12 10 103 72 32 2 4 11 194 169 8 3 9 11 23 5 22 -8 3 12 206 205 17
2 6 10 160 142 10 3 12 10 0 24 1 3 4 11 331 341 11 4 9 11 217 204 13 -7 3 12 146 154 20
3 6 10 391 417 9 4 12 10 107 43 24 4 4 11 221 220 11 5 9 11 114 86 23 -6 3 12 234 219 14
4 6 10 164 171 14 -1 13 10 166 135 24 5 4 11 109 103 18 6 9 11 238 236 14 -5 3 12 287 270 12
5 6 10 140 153 15 0 13 10 86 28 50 6 4 11 71 56 37 7 9 11 72 21 61 -4 3 12 212 221 12
6 6 10 61 50 53 1 13 10 126 120 28 7 4 11 257 230 14 -6 10 11 0 23 1 -3 3 12 403 405 9
7 6 10 27 21 26 1 0 11 110 119 8 8 4 11 12 25 11 -5 10 11 0 54 1 -2 3 12 335 347 9
8 6 10 57 49 56 2 0 11 836 812 11 9 4 11 279 245 21 -4 10 11 168 145 21 -1 3 12 182 172 6
9 6 10 83 38 36 3 0 11 147 139 9 -9 5 11 0 55 1 -3 10 11 91 123 91 0 3 12 383 372 6
-8 7 10 155 81 25 4 0 11 786 792 13 -8 5 11 33 64 32 -2 10 11 49 28 49 1 3 12 148 145 8
-7 7 10 189 181 20 5 0 11 89 75 21 -7 5 11 141 126 23 -1 10 11 140

100 22 2 3 12 347 353 8
-6 7 10 0 86 1 6 0 11 0 25 1 -6 5 11 332 360 19 0 10 11 90 53 39 3 3 12 436 431 9
-5 7 10 149 155 25 7 0 11 206 222 14 -5 5 11 183 176 16 1 10 11 135 111 19 4 3 12 228 226 10
-4 7 10 226 229 18 8 0 11 81 37 31 -4 5 11 406 396 11 2 10 11 78 14 37 5 3 12 264 265 12
-3 7 10 126 128 16 9 0 11 195 195 16 -3 5 11 250 244 12 3 10 11 81 115 36 6 3 12 211 200 16
-2 7 10 92 93 16 10 0 11 301 235 18 -2 5 11 474 462 9 4 10 11 138 125 17 7 3 12 115 148 27
-1 7 10 14 50 14 -10 1 11 50 28 49 -1 5 11 241 240 8 5 10 11 28 50 27 8 3 12 215 196 17
0 7 10 127 132 11 -9 1 11 236 233 16 0 5 11 247 240 7 6 10 11 63 26 62 9 3 12 48 23 47
1 7 10 44 30 44 -8 1 11 143 138 20 1 5 11 234 238 8 -5 11 11 44 31 43 -9 4 12 155 127 25
2 7 10 87 88 21 -7 1 11 377 364 13 2 5 11 491 499 8 -4 11 11 169 143 29 -8 4 12 168 182 20
3 7 10 142 148 18 -6 1 11 273 284 13 3 5 11 262 258 9 -3 11 11 118 114 40 -7 4 12 100 92 34
4 7 10 217 222 12 -5 1 11 283 292 12 4 5 11 405 408 9 -2 11 11 142 130 31 -6 4 12 81 79 29
5 7 10 101 101 21 -4 1 11 519 533 9 5 5 11 178 191 11 -1 11 11 112 110 30 -5 4 12 248 258 12
6 7 10 71 89 36 -3 1 11 364 347 8 6 5 11 347 333 12 0 11 11 24 13 24 -4 4 12 386 396 11
7 7 10 189 172 15 -2 1 11 583 578 7 7 5 11 134 133 18 1 11 11 132 130 24 -3 4 12 637 657 10
8 7 10 185 114 18 -1 1 11 668 651 8 8 5 11 57 45 57 2 11 11 116 136 23 -2 4 12 389 386 7
-8 8 10 63 18 62 0 1 11 192 198 7 9 5 11 89 71 34 3 11 11 132 120 18 -1 4 12 386 386 7
-7 8 10 148 145 23 1 1 11 641 635 8 -9 6 11 227 187 28 4 11 11 140 110 18 0 4 12 442 427 7
-6 8 10 79 18 79 2 1 11 533 528 10 -8 6 11 0 68 1 5 11 11 0 34 1 1 4 12 368 370 7
-5 8 10 203 229 15 3 1 11 364 352 10 -7 6 11 171 185 21 -3 12 11 0 52 1 2 4 12 399 399 9
-4 8 10 58 47 58 4 1 11 523 539 14 -6 6 11 143 138 22 -2 12 11 166 127 28 3 4 12 609 625 11
-3 8 10 131 141 22 5 1 11 291 283 11 -5 6 11 214 209 16 -1 12 11 136 109 27 4 4 12 420 412 12
-2 8 10 211 216 13 6 1 11 304 320 12 -4 6 11 541 558 12 0 12 11 0 6 1 5 4 12 261 264 12

Table 8. Observed and calculated structure factors for $C_{19}H_{19}BrNO_5S$
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h k l 10Fo 10Fc 10s h k l 10Fo 10Fc 10s h k l 10Fo 10Fc 10s h k l 10Fo 10Fc 10s h k l 10Fo 10Fc 10s

6 4 12 92 90 24 -5 10 12 164 120 26 2 3 13 881 875 13 1 8 13 227 221 11 1 2 14 102 87 9
7 4 12 110 84 23 -4 10 12 111 137 30 3 3 13 244 256 9 2 8 13 200 203 12 2 2 14 347 336 12
8 4 12 159 166 68 -3 10 12 176 186 24 4 3 13 581 589 10 3 8 13 200 205 13 3 2 14 253 250 11
9 4 12 91 112 59 -2 10 12 146 117 30 5 3 13 0 88 1 4 8 13 88 41 27 4 2 14 252 245 11
-9 5 12 135 57 30 -1 10 12 52 35 51 6 3 13 237 239 16 5 8 13 163 161 16 5 2 14 169 187 14
-8 5 12 135 114 122 0 10 12 197 169 18 7 3 13 142 139 22 6 8 13 128 137 19 6 2 14 143 125 20
-7 5 12 212 181 18 1 10 12 0 46 1 8 3 13 0 37 1 7 8 13 86 67 31 7 2 14 226 266 18
-6 5 12 191 214 15 2 10 12 131 108 20 9 3 13 123 76 36 -6 9 13 218 177 18 8 2 14 294 301 17
-5 5 12 329 314 12 3 10 12 188 193 14 -9 4 13 277 271 16 -5 9 13 110 45 35 9 2 14 79 101 78
-4 5 12 61 90 49 4 10 12 172 133 15 -8 4 13 143 103 22 -4 9 13 355 340 31 -9 3 14 63 46 62
-3 5 12 339 335 11 5 10 12 109 129 22 -7 4 13 292 271 15 -3 9 13 114 85 27 -8 3 14 115 80 25
-2 5 12 172 167 9 6 10 12 0 9 1 -6 4 13 199 207 14 -2 9 13 169 159 19 -7 3 14 207 194 16
-1 5 12 636 653 8 -5 11 12 176 188 32 -5 4 13 96 76 26 -1 9 13 51 79 50 -6 3 14 173 140 17
0 5 12 92 101 11 -4 11 12 50 67 50 -4 4 13 203 217 12 0 9 13 67 65 67 -5 3 14 357 370 11
1 5 12 606 625 9 -3 11 12 56 115 55 -3 4 13 486 496 9 1 9 13 12 77 12 -4 3 14 99 68 17
2 5 12 190 186 11 -2 11 12 97 72 48 -2 4 13 501 532 9 2 9 13 181 183 15 -3 3 14 135 141 12
3 5 12 335 331 9 -1 11 12 148 144 24 -1 4 13 642 650 9 3 9 13 94 76 23 -2 3 14 127 135 10
4 5 12 102 103 16 0 11 12 81 122 49 0 4 13 429 435 7 4 9 13 359 346 12 -1 3 14 89 86 10
5 5 12 342 337 10 1 11 12 179 144 17 1 4 13 648 655 8 5 9 13 69 37 54 0 3 14 39 31 38
6 5 12 210 221 14 2 11 12 63 69 62 2 4 13 528 550 9 6 9 13 190

170 16 1 3 14 82 73 18
7 5 12 189 183 15 3 11 12 157 131 25 3 4 13 444 450 12 -6 10 13 59 23 59 2 3 14 147 154 12
8 5 12 144 124 18 4 11 12 122 75 21 4 4 13 195 205 13 -5 10 13 132 111 30 3 3 14 111 113 16
9 5 12 89 52 35 5 11 12 226 215 14 5 4 13 101 102 22 -4 10 13 144 149 24 4 3 14 29 50 29
-8 6 12 144 147 35 -3 12 12 93 101 92 6 4 13 188 211 16 -3 10 13 155 133 21 5 3 14 310 340 15
-7 6 12 0 44 1 -2 12 12 181 179 30 7 4 13 277 278 16 -2 10 13 54 58 53 6 3 14 132 122 23
-6 6 12 97 78 35 -1 12 12 122 70 39 8 4 13 7 105 6 -1 10 13 265 258 16 7 3 14 201 186 19
-5 6 12 156 156 19 0 12 12 221 196 19 9 4 13 291 275 38 0 10 13 0 30 1 8 3 14 56 80 55
-4 6 12 162 161 14 1 12 12 84 72 45 -9 5 13 0 13 1 1 10 13 251 252 14 9 3 14 0 46 1
-3 6 12 99 95 19 2 12 12 207 188 17 -8 5 13 47 38 46 2 10 13 0 62 1 -9 4 14 114 102 29
-2 6 12 428 432 9 3 12 12 97 108 54 -7 5 13 127 80 27 3 10 13 130 118 18 -8 4 14 155 135 22
-1 6 12 88 91 15 1 0 13 597 575 8 -6 5 13 200 191 15 4 10 13 175 147 15 -7 4 14 132 132 22
0 6 12 292 303 13 2 0 13 86 83 14 -5 5 13 178 186 15 5 10 13 140 125 18 -6 4 14 176 170 31
1 6 12 118 106 12 3 0 13 200 199 9 -4 5 13 462 452 14 6 10 13 68 27 68 -5 4 14 283 284 12
2 6 12 455 458 9 4 0 13 287 282 15 -3 5 13 201 202 11 -4 11 13 148 180 24 -4 4 14 171 188 13
3 6 12 121 113 13 5 0 13 135 147 16 -2 5 13 443 441 10 -3 11 13 44 59 44 -3 4 14 47 65 46
4 6 12 185 189 11 6 0 13 69 43 37 -1 5 13 210 219 8 -2 11 13 78 73 77 -2 4 14 11 33 11
5 6 12 116 141 19 7 0 13 99 118 25 0 5 13 35 44 34 -1 11 13 0 38 1 -1 4 14 238 216 8
6 6 12 128 97 17 8 0 13 236 218 15 1 5 13 198 215 9 0 11 13 122 124 27 0 4 14 118 135 9
7 6 12 0 47 1 9 0 13 104 81 33 2 5 13 468 468 8 1 11 13 0 33 1 1 4 14 212 212 10
8 6 12 153 156 18 -9 1 13 121 111 24 3 5 13 201 220 10 2 11 13 72 76 45 2 4 14 39 46 38
-8 7 12 85 44 52 -8 1 13 84 92 35 4 5 13 461 448 10 3 11 13 47 54 47 3 4 14 64 63 63
-7 7 12 167 168 20 -7 1 13 202 201 18 5 5 13 215 216 17 4 11 13 179 165 17 4 4 14 189 192 13
-6 7 12 58 57 58 -6 1 13 172 183 15 6 5 13 224 206 17 -3 12 13 97

56 52 5 4 14 262 269 13
-5 7 12 318 309 15 -5 1 13 226 203 12 7 5 13 76 68 38 -2 12 13 100 43 53 6 4 14 180 154 16
-4 7 12 133 138 17 -4 1 13 252 262 10 8 5 13 0 22 1 -1 12 13 132 79 41 7 4 14 116 117 25
-3 7 12 421 422 12 -3 1 13 236 234 9 9 5 13 91 16 35 0 12 13 262 246 18 8 4 14 135 113 31
-2 7 12 110 103 18 -2 1 13 324 315 7 -8 6 13 137 100 36 1 12 13 64 47 63 9 4 14 86 81 64
-1 7 12 79 79 21 -1 1 13 116 110 9 -7 6 13 130 164 23 2 12 13 0 41 1 -8 5 14 58 47 58
0 7 12 0 32 1 0 1 13 0 28 1 -6 6 13 98 62 30 3 12 13 51 40 50 -7 5 14 69 108 68
1 7 12 94 94 15 1 1 13 88 93 11 -5 6 13 222 208 15 0 0 14 541 560 11 -6 5 14 82 50 32
2 7 12 106 100 15 2 1 13 309 301 8 -4 6 13 166 186 17 1 0 14 277 271 7 -5 5 14 171 154 15
3 7 12 451 469 11 3 1 13 243 227 11 -3 6 13 235 226 12 2 0 14 508 519 8 -4 5 14 468 478 12
4 7 12 148 151 15 4 1 13 309 304 12 -2 6 13 234 220 11 3 0 14 70 87 27 -3 5 14 114 112 16
5 7 12 321 307 12 5 1 13 177 173 13 -1 6 13 225 222 8 4 0 14 174 163 14 -2 5 14 295 293 10
6 7 12 29 68 29 6 1 13 237 225 13 0 6 13 244 260 10 5 0 14 162 138 17 -1 5 14 139 136 10
7 7 12 156 144 17 7 1 13 235 221 14 1 6 13 236 234 9 6 0 14 293 294 13 0 5 14 101 100 12
8 7 12 0 26 1 8 1 13 113 99 30 2 6 13 195 205 10 7 0 14 172 170 17 1 5 14 141 138 10
-7 8 12 93 83 38 9 1 13 165 114 22 3 6 13 189 187 11 8 0 14 433 402 14 2 5 14 287 279 9
-6 8 12 123 117 25 -9 2 13 244 208 18 4 6 13 180 173 11 9 0 14 167 121 24 3 5 14 49 38 48
-5 8 12 89 105 34 -8 2 13 195 162 16 5 6 13 162 189 15 -9 1 14 14 75 14 4 5 14 451 456 10
-4 8 12 80 107 34 -7 2 13 173 179 17 6 6 13 117 54 21 -8 1 14 156 156 19 5 5 14 140 137 18
-3 8 12 195 202 16 -6 2 13 172 200 16 7 6 13 144 147 17 -7 1 14 85 98 35 6 5 14 86 49 29
-2 8 12 235 235 15 -5 2 13 201 218 16 8 6 13 77 94 77 -6 1 14 204 211 15 7 5 14 114 113 28
-1 8 12 226 222 11 -4 2 13 104 95 15 -8 7 13 47 93 46 -5 1 14 558 566 13 8 5 14 0 45 1
0 8 12 401 411 13 -3 2 13 76 89 19 -7 7 13 113 107 29 -4 1 14 237 249 12 -8 6 14 183 164 57
1 8 12 208 236 11 -2 2 13 327 310 7 -6 7 13 221 193 27 -3 1 14 540

560 9 -7 6 14 38 40 37
2 8 12 204 216 12 -1 2 13 408 412 7 -5 7 13 216 192 17 -2 1 14 262 242 7 -6 6 14 331 304 16
3 8 12 219 221 16 0 2 13 227 221 7 -4 7 13 169 148 18 -1 1 14 348 335 7 -5 6 14 58 24 57
4 8 12 78 85 29 1 2 13 439 465 7 -3 7 13 139 134 16 0 1 14 151 139 9 -4 6 14 160 141 17
5 8 12 107 100 22 2 2 13 296 289 10 -2 7 13 213 232 14 1 1 14 348 338 7 -3 6 14 129 128 16
6 8 12 126 125 18 3 2 13 105 122 16 -1 7 13 86 112 19 2 1 14 268 260 10 -2 6 14 525 539 11
7 8 12 108 92 23 4 2 13 101 101 18 0 7 13 108 121 16 3 1 14 540 554 10 -1 6 14 47 33 46
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-6 9 12 218 176 23 6 2 13 179 189 18 2 7 13 190 196 10 5 1 14 551 563 11 1 6 14 69 40 20
-5 9 12 18 95 17 7 2 13 171 173 19 3 7 13 140 133 15 6 1 14 215 199 14 2 6 14 491 508 11
-4 9 12 162 131 20 8 2 13 139 142 24 4 7 13 165 149 15 7 1 14 144 110 18 3 6 14 118 128 15
-3 9 12 194 203 19 9 2 13 198 207 20 5 7 13 172 172 15 8 1 14 185 155 20 4 6 14 158 155 13
-2 9 12 196 199 17 -9 3 13 55 75 54 6 7 13 193 183 15 9 1 14 0 70 1 5 6 14 0 12 1
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4 9 12 131 132 18 -3 3 13 263 263 9 -4 8 13 17 39 16 -4 2 14 252 253 10 -6 7 14 193 188 19
5 9 12 0 56 1 -2 3 13 870 874 11 -3 8 13 225 207 15 -3 2 14 235 246 9 -5 7 14 264 253 16
6 9 12 195 170 16 -1 3 13 354 332 6 -2 8 13 222 215 21 -2 2 14 340 333 7 -4 7 14 278 310 16
7 9 12 0 84 1 0 3 13 152 144 8 -1 8 13 199 204 12 -1 2 14 99 95 11 -3 7 14 304 296 13
-6 10 12 104 24 37 1 3 13 344 327 10 0 8 13 117 134 16 0 2 14 645 658 8 -2 7 14 0 80 1

Table 8. Observed and calculated structure factors for C19H19BrNO5S
Page 8

h k l 10Fo 10Fc 10s h k l 10Fo 10Fc 10s h k l 10Fo 10Fc 10s h k l 10Fo 10Fc 10s h k l 10Fo 10Fc 10s

-1 7 14 178 188 12 7 1 15 99 114 24 3 6 15 39 67 39 -5 1 16 237 242 13 -7 6 16 156 134 30
0 7 14 80 37 22 8 1 15 92 112 42 4 6 15 140 140 14 -4 1 16 248 251 12 -6 6 16 264 229 26
1 7 14 183 185 12 9 1 15 74 97 73 5 6 15 142 147 17 -3 1 16 474 487 11 -5 6 16 165 129 18
2 7 14 97 87 17 -9 2 15 237 210 17 6 6 15 128 130 22 -2 1 16 70 70 20 -4 6 16 233 199 15
3 7 14 294 283 11 -8 2 15 120 149 27 7 6 15 141 140 19 -1 1 16 88 80 12 -3 6 16 109 99 22
4 7 14 304 315 12 -7 2 15 282 287 15 8 6 15 89 95 34 0 1 16 0 22 1 -2 6 16 166 163 16
5 7 14 260 267 13 -6 2 15 355 386 13 -7 7 15 153 124 39 1 1 16 111 107 10 -1 6 16 83 132 29
6 7 14 171 196 16 -5 2 15 285 295 13 -6 7 15 99 131 37 2 1 16 92 82 19 0 6 16 98 67 17
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-4 8 14 99 90 38 1 2 15 280 279 7 0 7 15 95 115 21 8 1 16 13 26 12 6 6 16 231 227 14
-3 8 14 71 49 58 2 2 15 109 123 18 1 7 15 202 191 11 9 1 16 0 57 1 7 6 16 117 126 22
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-1 8 14 207 212 12 4 2 15 125 130 17 3 7 15 94 127 20 -8 2 16 247 241 17 -7 7 16 142 101 76
0 8 14 378 397 11 5 2 15 316 304 12 4 7 15 190 200 14 -7 2 16 90 92 32 -6 7 16 243 216 24
1 8 14 218 226 11 6 2 15 342 374 18 5 7 15 114 113 27 -6 2 16 129 123 24 -5 7 16 194 198 18
2 8 14 107 110 20 7 2 15 279 269 17 6 7 15 100 109 26 -5 2 16 95

72 24 -4 7 16 189 189 17
3 8 14 99 46 23 8 2 15 85 150 42 7 7 15 153 129 19 -4 2 16 324 303 12 -3 7 16 181 160 21
4 8 14 114 94 20 9 2 15 204 191 20 -7 8 15 100 26 57 -3 2 16 203 189 10 -2 7 16 0 31 1
5 8 14 94 128 26 -9 3 15 96 47 34 -6 8 15 115 116 114 -2 2 16 499 503 9 -1 7 16 164 167 17
6 8 14 234 236 14 -8 3 15 132 126 24 -5 8 15 120 91 25 -1 2 16 68 61 17 0 7 16 0 27 1
7 8 14 187 150 17 -7 3 15 85 130 38 -4 8 15 136 129 32 0 2 16 475 455 8 1 7 16 166 155 13
-6 9 14 96 80 35 -6 3 15 112 110 23 -3 8 15 122 120 24 1 2 16 98 71 13 2 7 16 35 16 34
-5 9 14 99 69 41 -5 3 15 240 219 13 -2 8 15 113 74 28 2 2 16 499 511 10 3 7 16 142 153 14
-4 9 14 109 137 37 -4 3 15 469 502 11 -1 8 15 232 240 15 3 2 16 205 192 12 4 7 16 170 188 15
-3 9 14 95 100 57 -3 3 15 102 104 28 0 8 15 69 12 28 4 2 16 286 296 17 5 7 16 198 203 14
-2 9 14 75 93 46 -2 3 15 450 442 8 1 8 15 209 220 12 5 2 16 107 54 20 6 7 16 210 204 15
-1 9 14 161 162 28 -1 3 15 191 181 7 2 8 15 95 82 25 6 2 16 175 151 19 7 7 16 107 103 25
0 9 14 0 23 1 0 3 15 34 18 34 3 8 15 44 100 44 7 2 16 0 69 1 -7 8 16 90 41 89
1 9 14 142 159 18 1 3 15 139 155 13 4 8 15 101 112 22 8 2 16 252 258 18 -6 8 16 190 160 25
2 9 14 104 95 28 2 3 15 476 462 10 5 8 15 109 112 24 9 2 16 64 51 64 -5 8 16 168 150 21
3 9 14 112 104 21 3 3 15 90 101 19 6 8 15 100 102 39 -9 3 16 97 72 32 -4 8 16 250 232 33
4 9 14 158 143 16 4 3 15 523 530 13 7 8 15 91 44 28 -8 3 16 179 172 19 -3 8 16 125 95 23
5 9 14 127 89 20 5 3 15 239 240 16 -6 9 15 122 79 50 -7 3 16 122 140 24 -2 8 16 171 158 19
6 9 14 91 84 28 6 3 15 115 132 34 -5 9 15 98 101 43 -6 3 16 102 85 27 -1 8 16 151 155 19
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-4 10 14 120 129 120 8 3 15 127 130 27 -3 9 15 89 43 34 -4 3 16 0 27 1 1 8 16 146 145 17
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-2 10 14 67 65 67 -9 4 15 232 228 20 -1 9 15 49 69 48 -2 3 16 339 335 8 3 8 16 126 87 18
-1 10 14 77 91 77 -8 4 15 204 190 20 0 9 15 0 13 1 -1 3 16 285

273 6 4 8 16 227 226 14
0 10 14 0 27 1 -7 4 15 299 287 17 1 9 15 67 89 43 0 3 16 643 635 9 5 8 16 141 162 19
1 10 14 75 92 74 -6 4 15 185 194 16 2 9 15 197 204 15 1 3 16 297 273 10 6 8 16 146 155 19
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3 10 14 83 18 33 -4 4 15 355 360 11 4 9 15 246 206 14 3 3 16 344 327 11 -6 9 16 54 71 54
4 10 14 118 120 21 -3 4 15 364 376 10 5 9 15 86 95 36 4 3 16 0 55 1 -5 9 16 121 127 32
5 10 14 186 163 15 -2 4 15 398 417 8 6 9 15 77 56 39 5 3 16 180 168 18 -4 9 16 85 90 85
-4 11 14 65 59 64 -1 4 15 503 501 6 -5 10 15 167 114 25 6 3 16 0 92 1 -3 9 16 103 87 30
-3 11 14 62 124 61 0 4 15 72 99 15 -4 10 15 0 47 1 7 3 16 110 134 30 -2 9 16 252 233 16
-2 11 14 128 94 35 1 4 15 497 499 8 -3 10 15 0 69 1 8 3 16 165 174 23 -1 9 16 99 84 63
-1 11 14 0 69 1 2 4 15 400 405 10 -2 10 15 119 102 25 9 3 16 38 82 37 0 9 16 186 166 13
0 11 14 76 16 52 3 4 15 359 375 11 -1 10 15 267 256 21 -8 4 16 151 136 45 1 9 16 0 87 1
1 11 14 73 79 40 4 4 15 363 379 12 0 10 15 60 49 59 -7 4 16 183 169 18 2 9 16 222 223 16
2 11 14 107 83 36 5 4 15 312 334 15 1 10 15 232 247 15 -6 4 16 174 170 23 3 9 16 83 96 33
3 11 14 141 131 21 6 4 15 190 204 18 2 10 15 86 93 29 -5 4 16 349 343 11 4 9 16 123 111 19
4 11 14 79 47 39 7 4 15 313 297 35 3 10 15 84 75 32 -4 4 16 413 435 11 5 9 16 128 129 20
-2 12 14 168 144 32 8 4 15 206 203 38 4 10 15 56 57 55 -3 4 16 426 450 10 6 9 16 56 73 56
-1 12 14 121 143 41 9 4 15 168 216 41 5 10 15 122 121 23 -2 4 16 240 229 8 -5 10 16 207 183 22
0 12 14 231 199 19 -8 5 15 105 61 37 -4 11 15 174 140 24 -1 4 16 195 187 10 -4 10 16 41 55 41
1 12 14 100 142 35 -7 5 15 0 68 1 -3 11 15 0 59 1 0 4 16 332 326 8 -3 10 16 100 123 31
2 12 14 123 133 23 -6 5 15 237 233 20 -2 11 15 217 175 24 1 4 16 206 204 11 -2 10 16 61 32 61
1 0 15 407 401 7 -5 5 15 224 244 14 -1 11 15 0 81 1 2 4 16 185 199 16 -1 10 16 93 134 43
2 0 15 67 61 19 -4 5 15 569 577 25 0 11 15 193 152 23 3 4 16 457 452 18 0 10 16 128 121 21
3 0 15 66 72 29 -3 5 15 215 210 16 1 11 15 92 87 30 4 4 16 393

443 15 1 10 16 145 142 19
4 0 15 267 263 12 -2 5 15 487 506 10 2 11 15 144 160 20 5 4 16 311 333 15 2 10 16 32 34 31
5 0 15 76 20 29 -1 5 15 203 220 9 3 11 15 72 77 51 6 4 16 203 176 17 3 10 16 169 130 22
6 0 15 182 191 15 0 5 15 350 351 8 4 11 15 182 163 17 7 4 16 128 146 25 4 10 16 53 44 53
7 0 15 262 271 19 1 5 15 229 215 9 -2 12 15 158 128 31 8 4 16 149 133 31 5 10 16 193 184 17
8 0 15 34 29 33 2 5 15 485 495 9 -1 12 15 58 35 57 -8 5 16 112 66 30 -3 11 16 84 101 83
9 0 15 84 89 50 3 5 15 238 241 10 0 12 15 308 293 23 -7 5 16 32 120 31 -2 11 16 128 124 51
-9 1 15 89 111 38 4 5 15 558 606 30 1 12 15 0 50 1 -6 5 16 98 52 29 -1 11 16 125 82 35
-8 1 15 93 112 32 5 5 15 249 260 13 2 12 15 154 132 19 -5 5 16 192 187 16 0 11 16 123 84 35
-7 1 15 104 114 26 6 5 15 258 243 14 0 0 16 150 137 19 -4 5 16 134 132 17 1 11 16 93 92 28
-6 1 15 244 258 18 7 5 15 0 68 1 1 0 16 84 73 13 -3 5 16 185 185 15 2 11 16 140 125 31
-5 1 15 96 111 23 8 5 15 77 61 50 2 0 16 504 514 9 -2 5 16 145 148 14 3 11 16 130 99 22
-4 1 15 288 279 12 -8 6 15 0 78 1 3 0 16 0 20 1 -1 5 16 170 160 11 0 12 16 143 99 34
-3 1 15 209 205 11 -7 6 15 121 152 41 4 0 16 145 116 16 0 5 16 223 220 9 1 0 17 179 174 8
-2 1 15 279 279 9 -6 6 15 59 128 58 5 0 16 80 93 32 1 5 16 181 187 11 2 0 17 143 145 14
-1 1 15 412 420 7 -5 6 15 161 168 19 6 0 16 113 139 22 2 5 16 156 155 11 3 0 17 55 8 54
0 1 15 105 102 11 -4 6 15 74 118 38 7 0 16 270 281 14 3 5 16 215 209 10 4 0 17 429 445 12
1 1 15 403 404 7 -3 6 15 28 53 28 8 0 16 207 209 16 4 5 16 112 137 21 5 0 17 188 183 15
2 1 15 294 280 11 -2 6 15 103 96 18 9 0 16 118 87 33 5 5 16 146 167 18 6 0 17 246 243 17
3 1 15 189 184 12 -1 6 15 220 221 10 -9 1 16 71 64 61 6 5 16 24 50 24 7 0 17 272 264 14
4 1 15 250 232 12 0 6 15 208 233 11 -8 1 16 0 27 1 7 5 16 136 109 31 8 0 17 62 74 61
5 1 15 75 106 30 1 6 15 254 257 10 -7 1 16 216 217 16 8 5 16 67 53 67 9 0 17 215 177 21
6 1 15 194 225 15 2 6 15 85 95 20 -6 1 16 97 135 25 -8 6 16 128 122 28 -9 1 17 173 169 19

Table 8. Observed and calculated structure factors for $C_{19}H_{19}BrNO_5S$
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h k l 10Fo 10Fc 10s h k l 10Fo 10Fc 10s h k l 10Fo 10Fc 10s h k l 10Fo 10Fc 10s h k l 10Fo 10Fc 10s

-8 1 17 180 117 18 -7 6 17 140 166 27 0 1 18 314 306 8 4 6 18 88 48 22 -2 2 19 421 424 13
-7 1 17 108 99 26 -6 6 17 171 147 21 1 1 18 247 255 11 5 6 18 98 104 25 -1 2 19 144 144 12
-6 1 17 186 207 16 -5 6 17 125 77 23 2 1 18 152 156 14 6 6 18 51 25 50 0 2 19 173 186 9
-5 1 17 159 166 16 -4 6 17 253 270 15 3 1 18 55 56 54 7 6 18 175 148 19 1 2 19 160 145 17
-4 1 17 326 336 12 -3 6 17 270 271 14 4 1 18 257 279 12 -7 7 18 42 23 41 2 2 19 407 409 12
-3 1 17 244 233 12 -2 6 17 216 215 12 5 1 18 87 67 27 -6 7 18 0 27 1 3 2 19 0 14 1
-2 1 17 261 261 9 -1 6 17 469 469 14 6 1 18 81 22 31 -5 7 18 120 114 24 4 2 19 175 155 15
-1 1 17 469 468 8 0 6 17 201 181 11 7 1 18 67 53 66 -4 7 18 0 82 1 5 2 19 156 136 22
0 1 17 46 9 33 1 6 17 460 469 12 8 1 18 80 84 54 -3 7 18 62 57 61 6 2 19 294 308 17
1 1 17 497 491 8 2 6 17 206 209 11 -8 2 18 114 125 44 -2 7 18 176 186 17 7 2 19 159 138 23
2 1 17 295 302 11 3 6 17 242 260 11 -7 2 18 185 199 20 -1 7 18 220 211 16 8 2 19 106 121 34
3 1 17 250 236 12 4 6 17 263 258 11 -6 2 18 229 215 15 0 7 18 60 25 47 -8 3 19 0 54 1
4 1 17 314 317 17 5 6 17 81 73 27 -5 2 18 302 312 13 1 7 18 219 199 12 -7 3 19 191 194 18
5 1 17 161 175 15 6 6 17 150 143 18 -4 2 18 168 176 17 2 7 18 190 196 13 -6 3 19 53 60 53
6 1 17 195 189 15 7 6 17 187 164 18 -3 2 18 242 235 10 3 7 18 52 32 51 -5 3 19 182 182 23
7 1 17 0 90 1 -7 7 17 175 159 29 -2 2 18 186 177 11 4 7 18 76 59 34 -4 3 19 120 118 26
8 1 17 136 122 43 -6 7 17 70 61 69 -1 2 18 87 104 15 5 7 18 116 131 22 -3 3 19 184 183 12
9 1 17 191 180 21 -5 7 17 226 244 40 0 2 18 406 388 8 6 7 18 0 25 1 -2 3 19 348 347 10
-9 2 17 87 77 40 -4 7 17 188 187 18 1 2 18 101 119 18 7 7 18 0 18 1 -1 3 19 552 554 9
-8 2 17 197 176 17 -3 7 17 134 139 21 2 2 18 178 196 13 -6 8 18 39

39 38 0 3 19 130 111 12
-7 2 17 187 213 17 -2 7 17 232 227 15 3 2 18 307 279 13 -5 8 18 107 129 31 1 3 19 565 568 13
-6 2 17 313 329 14 -1 7 17 269 247 19 4 2 18 155 169 15 -4 8 18 112 76 42 2 3 19 326 327 12
-5 2 17 41 100 41 0 7 17 13 19 13 5 2 18 300 300 16 -3 8 18 161 128 37 3 3 19 219 219 13
-4 2 17 215 205 18 1 7 17 252 247 11 6 2 18 231 233 18 -2 8 18 124 99 24 4 3 19 111 107 24
-3 2 17 91 91 18 2 7 17 255 256 11 7 2 18 162 164 27 -1 8 18 133 97 21 5 3 19 205 185 35
-2 2 17 245 235 10 3 7 17 104 126 18 8 2 18 123 131 31 0 8 18 111 99 38 6 3 19 105 61 31
-1 2 17 58 82 23 4 7 17 147 190 18 -8 3 18 0 46 1 1 8 18 120 120 18 7 3 19 215 206 23
0 2 17 47 78 34 5 7 17 244 251 14 -7 3 18 29 31 29 2 8 18 77 106 30 8 3 19 60 53 59
1 2 17 45 29 44 6 7 17 0 46 1 -6 3 18 0 88 1 3 8 18 145 133 20 -8 4 19 41 77 40
2 2 17 206 204 12 7 7 17 166 154 31 -5 3 18 260 242 14 4 8 18 73 65 39 -7 4 19 132 152 22
3 2 17 90 79 26 -6 8 17 62 87 62 -4 3 18 110 90 21 5 8 18 110 105 23 -6 4 19 289 285 15
4 2 17 192 214 14 -5 8 17 134 102 23 -3 3 18 436 452 11 6 8 18 105 63 24 -5 4 19 121 122 22
5 2 17 150 134 16 -4 8 17 157 130 51 -2 3 18 296 287 10 -5 9 18 163 141 26 -4 4 19 205 191 12
6 2 17 342 344 16 -3 8 17 71 130 71 -1 3 18 406 430 8 -4 9 18 94 82 38 -3 4 19 121 109 15
7 2 17 193 189 19 -2 8 17 157 143 19 0 3 18 44 37 43 -3 9 18 201 175 37 -2 4 19 292 300 10
8 2 17 226 182 20 -1 8 17 0 15 1 1 3 18 447 441 16 -2 9 18 237 227 16 -1 4 19 50 48 50
9 2 17 123 56 28 0 8 17 108 101 17 2 3 18 251 259 13 -1 9 18 202 141 17 0 4 19 125 102 12
-8 3 17 108 79 29 1 8 17 49 41 48 3 3 18 473 479 11 0 9 18 53 45 52 1 4 19 54 34 53
-7 3 17 0 75 1 2 8 17 138 154 19 4 3 18 88 76 34 1 9 18 158 132 17 2 4 19 341 339 14
-6 3 17 75 78 41 3 8 17 114 122 27 5 3 18 254 242 16 2 9 18 224 223 16 3 4 19 113 114 24
-5 3 17 48 47 47 4 8 17 140 139 18 6 3 18 131 91 24 3 9 18 182 174 17 4 4 19 167 178 19
-4 3 17 221 215 13 5 8 17 113 107 21 7 3 18 0 41 1 4 9 18 109 103 25 5 4 19 129 106 25
-3 3 17 119 120 14 6 8 17 100 98 32 8 3 18 82 57 51 5 9 18 169

134 17 6 4 19 276 272 21
-2 3 17 181 182 10 -5 9 17 85 122 85 -8 4 18 189 180 19 -4 10 18 124 81 65 7 4 19 152 126 24
-1 3 17 276 266 11 -4 9 17 47 53 46 -7 4 18 126 138 24 -3 10 18 152 142 25 8 4 19 56 60 55
0 3 17 95 76 14 -3 9 17 98 73 34 -6 4 18 211 212 16 -2 10 18 104 135 37 -7 5 19 80 40 48
1 3 17 271 275 11 -2 9 17 97 47 31 -5 4 18 286 284 14 -1 10 18 135 126 37 -6 5 19 97 94 29
2 3 17 143 139 14 -1 9 17 97 93 36 -4 4 18 56 91 56 0 10 18 162 150 46 -5 5 19 101 104 46
3 3 17 131 126 17 0 9 17 0 56 1 -3 4 18 244 239 11 1 10 18 76 134 45 -4 5 19 110 139 19
4 3 17 229 238 16 1 9 17 115 86 21 -2 4 18 183 180 11 2 10 18 97 144 33 -3 5 19 100 96 18
5 3 17 44 36 43 2 9 17 42 55 41 -1 4 18 416 428 8 3 10 18 168 144 18 -2 5 19 85 102 23
6 3 17 95 65 33 3 9 17 79 64 36 0 4 18 411 412 9 4 10 18 102 82 29 -1 5 19 224 240 12
7 3 17 0 57 1 4 9 17 58 59 57 1 4 18 391 409 11 -2 11 18 168 148 29 0 5 19 248 278 14
8 3 17 113 64 34 5 9 17 99 107 26 2 4 18 178 172 17 -1 11 18 89 61 53 1 5 19 237 249 11
-8 4 17 190 180 19 -4 10 17 66 36 65 3 4 18 223 231 15 0 11 18 165 138 30 2 5 19 116 82 18
-7 4 17 98 103 28 -3 10 17 0 85 1 4 4 18 94 87 35 1 11 18 0 54 1 3 5 19 59 77 59
-6 4 17 151 174 19 -2 10 17 68 63 68 5 4 18 279 289 16 2 11 18 167 167 19 4 5 19 134 147 23
-5 4 17 210 209 15 -1 10 17 0 61 1 6 4 18 199 219 21 1 0 19 260 262 9 5 5 19 87 117 40
-4 4 17 33 44 32 0 10 17 71 101 70 7 4 18 179 150 20 2 0 19 276 258 12 6 5 19 128 94 35
-3 4 17 129 139 14 1 10 17 86 70 29 8 4 18 183 180 33 3 0 19 43 23 43 7 5 19 71 35 70
-2 4 17 189 203 11 2 10 17 0 44 1 -8 5 18 231 205 18 4 0 19 179 189 14 -7 6 19 98 119 38
-1 4 17 76 64 16 3 10 17 68 78 62 -7 5 18 94 140 45 5 0 19 233 215 14 -6 6 19 84 65 42
0 4 17 50 64 33 4 10 17 0 10 1 -6 5 18 102 87 29 6 0 19 166 199 17 -5 6 19 201 213 15
1 4 17 100 102 18 -3 11 17 0 85 1 -5 5 18 82 58 26 7 0 19 226 194 16 -4 6 19 130 92 18
2 4 17 169 191 16 -2 11 17 32 106 31 -4 5 18 286 305 11 8 0 19 94 150 46 -3 6 19 147 172 16
3 4 17 158 147 17 -1 11 17 127 103 34 -3 5 18 197 217 12 -8 1 19

152 143 21 -2 6 19 129 153 20
4 4 17 0 54 1 0 11 17 235 193 23 -2 5 18 303 314 12 -7 1 19 102 126 28 -1 6 19 251 273 14
5 4 17 173 181 18 1 11 17 95 81 30 -1 5 18 73 50 24 -6 1 19 112 138 23 0 6 19 163 170 18
6 4 17 182 168 19 2 11 17 112 110 33 0 5 18 402 397 13 -5 1 19 234 232 14 1 6 19 257 262 11
7 4 17 110 101 31 3 11 17 111 63 26 1 5 18 51 46 50 -4 1 19 199 199 14 2 6 19 108 120 18
8 4 17 191 186 45 0 0 18 276 263 12 2 5 18 337 338 10 -3 1 19 223 221 12 3 6 19 163 177 19
-8 5 17 99 98 35 1 0 18 19 28 19 3 5 18 226 243 13 -2 1 19 388 401 11 4 6 19 114 102 20
-7 5 17 48 22 48 2 0 18 95 89 20 4 5 18 307 303 15 -1 1 19 372 377 10 5 6 19 235 206 13
-6 5 17 164 150 18 3 0 18 17 82 16 5 5 18 0 59 1 0 1 19 46 13 45 6 6 19 125 39 24
-5 5 17 164 130 14 4 0 18 41 30 41 6 5 18 43 79 43 1 1 19 380 393 11 7 6 19 125 121 25
-4 5 17 181 186 12 5 0 18 169 164 15 7 5 18 169 143 28 2 1 19 385 402 12 -6 7 19 105 53 33
-3 5 17 208 203 11 6 0 18 90 93 30 8 5 18 214 212 26 3 1 19 234 243 13 -5 7 19 159 161 17
-2 5 17 463 462 11 7 0 18 150 113 19 -7 6 18 181 140 21 4 1 19 186 199 15 -4 7 19 172 183 19
-1 5 17 204 202 11 8 0 18 0 23 1 -6 6 18 63 49 63 5 1 19 201 230 15 -3 7 19 149 108 24
0 5 17 286 291 9 9 0 18 99 6 41 -5 6 18 115 91 21 6 1 19 123 138 21 -2 7 19 171 165 23
1 5 17 171 161 12 -8 1 18 85 115 84 -4 6 18 64 59 55 7 1 19 141 149 25 -1 7 19 246 227 15
2 5 17 429 433 11 -7 1 18 0 45 1 -3 6 18 223 203 13 8 1 19 127 134 30 0 7 19 0 68 1
3 5 17 157 168 14 -6 1 18 0 13 1 -2 6 18 168 147 14 -8 2 19 145 111 28 1 7 19 231 237 12
4 5 17 231 233 15 -5 1 18 67 46 42 -1 6 18 194 211 15 -7 2 19 144 141 20 2 7 19 159 161 23
5 5 17 142 140 22 -4 1 18 275 291 12 0 6 18 163 154 12 -6 2 19 289 293 14 3 7 19 137 120 17
6 5 17 142 152 22 -3 1 18 109 96 19 1 6 18 218 206 11 -5 2 19 172 153 17 4 7 19 176 179 15
7 5 17 108 2 44 -2 1 18 194 204 10 2 6 18 168 151 13 -4 2 19 155 156 17 5 7 19 144 148 23
8 5 17 118 84 28 -1 1 18 275 263 8 3 6 18 210 233 12 -3 2 19 0 6 1 6 7 19 54 50 54

Table 8. Observed and calculated structure factors for C19H19BrNO5S
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h k l 10Fo 10Fc 10s h k l 10Fo 10Fc 10s h k l 10Fo 10Fc 10s h k l 10Fo 10Fc 10s h k l 10Fo 10Fc 10s

-6 8 19 139 171 23 1 3 20 275 278 14 -1 10 20 87 42 35 4 5 21 106 77 30 0 2 22 239 219 12
-5 8 19 120 107 60 2 3 20 223 233 19 0 10 20 128 151 49 5 5 21 121 99 28 1 2 22 182 169 14
-4 8 19 210 195 34 3 3 20 99 112 28 1 10 20 80 37 79 6 5 21 234 227 24 2 2 22 169 154 17
-3 8 19 82 66 54 4 3 20 61 76 61 2 10 20 14 68 14 7 5 21 109 64 47 3 2 22 275 253 13
-2 8 19 221 232 21 5 3 20 98 97 50 3 10 20 42 52 42 -6 6 21 0 43 1 4 2 22 172 163 15
-1 8 19 74 88 50 6 3 20 0 96 1 1 0 21 86 99 23 -5 6 21 120 107 26 5 2 22 170 147 21
0 8 19 335 349 15 7 3 20 194 184 29 2 0 21 170 160 14 -4 6 21 0 27 1 6 2 22 89 71 45
1 8 19 72 86 29 8 3 20 59 47 58 3 0 21 120 113 19 -3 6 21 228 212 16 7 2 22 166 169 24
2 8 19 199 212 14 -7 4 20 166 153 21 4 0 21 225 232 14 -2 6 21 115 118 23 -7 3 22 120 150 27
3 8 19 18 71 18 -6 4 20 130 148 37 5 0 21 82 28 30 -1 6 21 133 88 19 -6 3 22 110 126 29
4 8 19 225 224 14 -5 4 20 142 136 19 6 0 21 215 211 16 0 6 21 132 105 22 -5 3 22 141 139 19
5 8 19 128 99 20 -4 4 20 129 82 24 7 0 21 0 7 1 1 6 21 91 81 21 -4 3 22 145 164 19
6 8 19 227 183 15 -3 4 20 223 225 15 8 0 21 98 132 41 2 6 21 88 98 34 -3 3 22 118 133 20
-5 9 19 0 51 1 -2 4 20 110 108 16 -8 1 21 49 90 49 3 6 21 205 221 14 -2 3 22 144 144 14
-4 9 19 129 108 28 -1 4 20 126 114 14 -7 1 21 17 52 16 4 6 21 0 25 1 -1 3 22 102 113 19
-3 9 19 207 105 21 0 4 20 114 126 17 -6 1 21 170 176 18 5 6 21 96 100 28 0 3 22 226 229 12
-2 9 19 78 66 44 1 4 20 99 104 20 -5 1 21 73 56 42 6 6 21 46 36 45 1 3 22 107 115 20
-1 9 19 150 140 21 2 4 20 91 109 32 -4 1 21 80 90 33 -6 7 21 113 103 32 2 3 22 190 174 14
0 9 19 99 92 41 3 4 20 191 203 18 -3 1 21 118 137 23 -5 7 21 68 75 68 3 3 22 113 136 25
1 9 19 153 137 19 4 4 20 127 82 23 -2 1 21 101 63 20 -4 7 21 163

176 22 4 3 22 168 157 21
2 9 19 25 70 24 5 4 20 169 170 30 -1 1 21 102 80 16 -3 7 21 89 63 46 5 3 22 77 131 76
3 9 19 134 117 22 6 4 20 139 163 24 0 1 21 192 173 11 -2 7 21 118 41 34 6 3 22 137 99 25
4 9 19 144 116 26 7 4 20 88 162 49 1 1 21 0 65 1 -1 7 21 78 2 37 7 3 22 127 153 33
5 9 19 22 54 21 -7 5 20 129 108 25 2 1 21 28 57 28 0 7 21 45 78 45 -7 4 22 23 89 23
-4 10 19 144 143 36 -6 5 20 63 108 62 3 1 21 130 148 18 1 7 21 32 37 31 -6 4 22 0 56 1
-3 10 19 68 33 68 -5 5 20 119 84 23 4 1 21 98 86 23 2 7 21 0 48 1 -5 4 22 97 123 28
-2 10 19 96 72 33 -4 5 20 134 131 23 5 1 21 59 45 59 3 7 21 0 69 1 -4 4 22 40 60 40
-1 10 19 116 133 35 -3 5 20 124 153 15 6 1 21 147 161 25 4 7 21 140 171 18 -3 4 22 92 97 25
0 10 19 140 117 29 -2 5 20 50 56 50 7 1 21 59 41 58 5 7 21 89 67 51 -2 4 22 194 179 14
1 10 19 147 131 18 -1 5 20 195 188 13 8 1 21 62 68 61 6 7 21 101 89 32 -1 4 22 77 44 24
2 10 19 32 65 31 0 5 20 272 286 17 -8 2 21 0 19 1 -5 8 21 84 57 45 0 4 22 190 179 13
3 10 19 40 37 39 1 5 20 203 182 12 -7 2 21 78 76 63 -4 8 21 63 39 62 1 4 22 51 36 50
4 10 19 185 149 18 2 5 20 53 63 53 -6 2 21 217 220 18 -3 8 21 117 70 30 2 4 22 190 166 18
-1 11 19 157 114 26 3 5 20 122 153 33 -5 2 21 273 263 14 -2 8 21 84 71 63 3 4 22 159 121 20
0 11 19 111 80 41 4 5 20 151 135 21 -4 2 21 240 242 14 -1 8 21 137 134 21 4 4 22 0 63 1
1 11 19 70 99 70 5 5 20 131 88 24 -3 2 21 205 214 14 0 8 21 25 40 25 5 4 22 126 121 26
0 0 20 165 175 14 6 5 20 36 102 36 -2 2 21 87 58 25 1 8 21 123 125 25 6 4 22 96 56 40
1 0 20 85 93 22 7 5 20 14 88 13 -1 2 21 218 204 11 2 8 21 71 70 36 7 4 22 62 83 62
2 0 20 259 261 12 -7 6 20 71 97 71 0 2 21 99 59 19 3 8 21 84 60 35 -7 5 22 71 91 71
3 0 20 432 438 12 -6 6 20 0 54 1 1 2 21 191 197 14 4 8 21 89 74 35 -6 5 22 127 120 25
4 0 20 23 21 23 -5 6 20 346 323 16 2 2 21 67 84 36 5 8 21 75 45 52 -5 5 22 162 137 18
5 0 20 212 203 15 -4 6 20 49 76 49 3 2 21 179 202 20 -4 9 21 96 87 40 -4 5 22 0 49 1
6 0 20 85 122 34 -3 6 20 451 444 13 4 2 21 256 254 13 -3 9 21 60

34 60 -3 5 22 97 103 21
7 0 20 46 47 45 -2 6 20 117 107 26 5 2 21 244 242 20 -2 9 21 138 32 26 -2 5 22 156 163 17
8 0 20 54 21 54 -1 6 20 274 284 15 6 2 21 169 198 22 -1 9 21 250 235 16 -1 5 22 173 178 17
-8 1 20 131 170 25 0 6 20 110 118 23 7 2 21 71 81 71 0 9 21 186 126 19 0 5 22 174 159 18
-7 1 20 178 161 19 1 6 20 280 309 11 8 2 21 0 22 1 1 9 21 254 234 27 1 5 22 180 171 15
-6 1 20 184 164 17 2 6 20 92 103 22 -7 3 21 244 214 16 2 9 21 0 26 1 2 5 22 170 152 14
-5 1 20 129 124 20 3 6 20 429 439 12 -6 3 21 87 92 32 3 9 21 41 15 40 3 5 22 88 94 37
-4 1 20 207 206 14 4 6 20 56 74 55 -5 3 21 208 222 16 4 9 21 71 82 71 4 5 22 73 58 57
-3 1 20 73 72 31 5 6 20 325 321 13 -4 3 21 102 115 30 -2 10 21 164 169 27 5 5 22 127 118 26
-2 1 20 276 290 12 6 6 20 60 35 59 -3 3 21 101 123 23 -1 10 21 100 55 48 6 5 22 149 133 24
-1 1 20 216 219 10 7 6 20 121 99 27 -2 3 21 158 159 13 0 10 21 0 51 1 7 5 22 82 65 44
0 1 20 527 514 8 -6 7 20 209 177 20 -1 3 21 343 344 19 1 10 21 73 53 73 -6 6 22 119 67 30
1 1 20 227 230 12 -5 7 20 139 132 19 0 3 21 346 315 12 2 10 21 192 182 16 -5 6 22 166 178 22
2 1 20 229 259 13 -4 7 20 48 39 47 1 3 21 353 341 12 0 0 22 232 216 18 -4 6 22 98 79 25
3 1 20 23 61 23 -3 7 20 74 75 73 2 3 21 155 154 15 1 0 22 236 217 12 -3 6 22 94 98 33
4 1 20 182 198 15 -2 7 20 200 199 22 3 3 21 131 99 22 2 0 22 125 94 18 -2 6 22 13 43 13
5 1 20 107 127 22 -1 7 20 98 91 29 4 3 21 103 117 31 3 0 22 218 229 14 -1 6 22 123 141 31
6 1 20 169 162 17 0 7 20 152 140 20 5 3 21 254 234 18 4 0 22 80 94 47 0 6 22 238 237 16
7 1 20 166 181 24 1 7 20 76 96 29 6 3 21 57 94 57 5 0 22 0 47 1 1 6 22 148 153 21
8 1 20 172 171 33 2 7 20 199 177 13 7 3 21 224 236 20 6 0 22 133 145 24 2 6 22 0 58 1
-8 2 20 28 41 27 3 7 20 31 74 31 -7 4 21 60 49 59 7 0 22 0 26 1 3 6 22 114 107 20
-7 2 20 92 102 33 4 7 20 0 28 1 -6 4 21 141 129 22 8 0 22 151 149 26 4 6 22 100 70 24
-6 2 20 73 81 48 5 7 20 157 134 20 -5 4 21 152 126 18 -8 1 22 144 92 22 5 6 22 203 166 15
-5 2 20 130 147 25 6 7 20 229 183 18 -4 4 21 253 267 14 -7 1 22 145

128 30 6 6 22 85 62 45
-4 2 20 134 143 23 -5 8 20 166 201 27 -3 4 21 175 179 13 -6 1 22 147 166 28 -5 7 22 128 132 26
-3 2 20 204 201 14 -4 8 20 57 85 57 -2 4 21 127 112 14 -5 1 22 106 133 25 -4 7 22 86 80 51
-2 2 20 180 188 11 -3 8 20 184 137 23 -1 4 21 136 127 15 -4 1 22 134 126 19 -3 7 22 137 98 25
-1 2 20 80 49 20 -2 8 20 162 121 42 0 4 21 110 116 19 -3 1 22 123 113 19 -2 7 22 151 170 26
0 2 20 131 121 14 -1 8 20 142 88 20 1 4 21 125 130 16 -2 1 22 160 151 15 -1 7 22 119 80 30
1 2 20 75 56 27 0 8 20 148 147 19 2 4 21 109 102 41 -1 1 22 225 213 12 0 7 22 369 359 15
2 2 20 191 192 13 1 8 20 115 111 18 3 4 21 200 187 17 0 1 22 129 154 20 1 7 22 97 68 32
3 2 20 213 192 14 2 8 20 118 128 20 4 4 21 258 244 17 1 1 22 208 208 13 2 7 22 178 173 14
4 2 20 159 166 16 3 8 20 122 128 24 5 4 21 81 110 45 2 1 22 162 166 17 3 7 22 78 95 31
5 2 20 126 154 25 4 8 20 109 86 26 6 4 21 129 122 27 3 1 22 98 109 23 4 7 22 121 76 20
6 2 20 117 102 29 5 8 20 148 183 31 7 4 21 98 38 36 4 1 22 140 128 19 5 7 22 168 147 21
7 2 20 124 103 30 -4 9 20 77 119 77 -7 5 21 84 53 40 5 1 22 130 147 20 -5 8 22 187 171 18
8 2 20 0 32 1 -3 9 20 98 80 34 -6 5 21 248 221 21 6 1 22 154 151 24 -4 8 22 59 48 58
-8 3 20 100 87 31 -2 9 20 119 132 52 -5 5 21 84 100 34 7 1 22 108 133 41 -3 8 22 168 176 24
-7 3 20 171 189 20 -1 9 20 96 93 63 -4 5 21 32 79 32 8 1 22 78 114 78 -2 8 22 134 112 27
-6 3 20 102 121 27 0 9 20 39 22 38 -3 5 21 107 123 19 -7 2 22 162 165 20 -1 8 22 264 251 21
-5 3 20 70 98 70 1 9 20 86 92 63 -2 5 21 218 231 15 -6 2 22 44 61 44 0 8 22 157 140 20
-4 3 20 60 83 59 2 9 20 91 107 29 -1 5 21 174 180 17 -5 2 22 133 115 21 1 8 22 227 245 17
-3 3 20 81 98 22 3 9 20 112 73 26 0 5 21 69 69 49 -4 2 22 130 147 35 2 8 22 75 122 37
-2 3 20 251 261 10 4 9 20 126 113 32 1 5 21 192 188 12 -3 2 22 248 241 13 3 8 22 206 185 17
-1 3 20 238 267 10 -3 10 20 0 73 1 2 5 21 215 241 12 -2 2 22 125 139 27 4 8 22 0 55 1
0 3 20 125 112 15 -2 10 20 115 65 29 3 5 21 101 120 30 -1 2 22 192 188 11 5 8 22 212 175 18

Table 8. Observed and calculated structure factors for $C_{19}H_{19}BrNO_5S$
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h k l 10Fo 10Fc 10s h k l 10Fo 10Fc 10s h k l 10Fo 10Fc 10s h k l 10Fo 10Fc 10s h k l 10Fo 10Fc 10s

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-2 9 22 114 81 34 6 5 23 100 99 51 2 3 24 79 68 30 -6 2 25 53 62 53 -3 1 26 227 206 15
-1 9 22 185 113 45 -6 6 23 142 106 25 3 3 24 132 150 23 -5 2 25 37 45 37 -2 1 26 111 70 26
0 9 22 63 13 62 -5 6 23 101 49 47 4 3 24 99 28 33 -4 2 25 47 40 47 -1 1 26 212 205 27
1 9 22 123 118 26 -4 6 23 129 117 22 5 3 24 273 262 18 -3 2 25 97 82 26 0 1 26 80 83 80
2 9 22 117 102 22 -3 6 23 101 122 44 6 3 24 153 162 25 -2 2 25 63 86 63 1 1 26 186 214 29
3 9 22 107 103 28 -2 6 23 194 225 22 7 3 24 94 75 39 -1 2 25 0 33 1 2 1 26 80 69 33
-1 10 22 168 120 19 -1 6 23 346 362 26 -6 4 24 136 138 22 0 2 25 130 102 20 3 1 26 234 208 17
0 10 22 93 53 45 0 6 23 87 65 32 -5 4 24 93 89 32 1 2 25 74 62 35 4 1 26 0 7 1
1 10 22 26 115 26 1 6 23 373 356 15 -4 4 24 88 85 29 2 2 25 124 103 19 5 1 26 97 73 39
1 0 23 258 259 12 2 6 23 218 217 13 -3 4 24 157 133 17 3 2 25 119 103 21 6 1 26 141 118 28
2 0 23 111 100 21 3 6 23 138 133 17 -2 4 24 171 163 14 4 2 25 0 57 1 -6 2 26 55 13 54
3 0 23 126 97 19 4 6 23 126 123 21 -1 4 24 58 46 58 5 2 25 93 40 38 -5 2 26 171 140 18
4 0 23 107 107 24 5 6 23 86 43 32 0 4 24 155 121 19 6 2 25 0 64 1 -4 2 26 0 59 1
5 0 23 71 23 48 6 6 23 99 103 35 1 4 24 70 56 52 -6 3 25 46 47 46 -3 2 26 140 104 18
6 0 23 204 200 16 -5 7 23 97 73 35 2 4 24 207 185 18 -5 3 25 32 26 32 -2 2 26 154 175 21
7 0 23 166 172 25 -4 7 23 277 271 28 3 4 24 163 132 21 -4 3 25 57 34 56 -1 2 26 0 74 1
-7 1 23 213 156 20 -3 7 23 67 22 67 4 4 24 101 99 31 -3 3 25 51 33 50 0 2 26 73 24 73
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-5 1 23 157 151 18 -1 7 23 0 24 1 6 4 24 169 144 24 -1 3 25 150

130 25 2 2 26 162 167 17
-4 1 23 106 130 24 0 7 23 141 168 21 -6 5 24 108 107 38 0 3 25 303 305 15 3 2 26 85 98 33
-3 1 23 193 181 14 1 7 23 61 22 61 -5 5 24 97 56 29 1 3 25 133 130 23 4 2 26 80 66 57
-2 1 23 188 208 14 2 7 23 94 95 27 -4 5 24 161 128 17 2 3 25 64 71 64 5 2 26 162 138 23
-1 1 23 388 395 12 3 7 23 0 28 1 -3 5 24 108 106 50 3 3 25 52 32 52 6 2 26 34 24 34
0 1 23 0 34 1 4 7 23 233 258 16 -2 5 24 59 83 58 4 3 25 90 56 39 -6 3 26 262 253 16
1 1 23 374 386 12 5 7 23 113 86 29 -1 5 24 68 67 52 5 3 25 0 30 1 -5 3 26 73 67 48
2 1 23 210 216 14 -4 8 23 94 68 93 0 5 24 78 22 63 6 3 25 82 70 53 -4 3 26 106 67 27
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4 1 23 120 125 22 -2 8 23 0 9 1 2 5 24 82 72 28 -5 4 25 52 97 51 -2 3 26 0 44 1
5 1 23 190 168 18 -1 8 23 108 61 39 3 5 24 91 93 37 -4 4 25 0 28 1 -1 3 26 102 83 36
6 1 23 136 108 26 0 8 23 149 139 21 4 5 24 164 133 22 -3 4 25 167 160 19 0 3 26 165 183 17
7 1 23 199 148 22 1 8 23 106 75 47 5 5 24 107 77 30 -2 4 25 30 30 30 1 3 26 98 86 36
-7 2 23 97 89 33 2 8 23 62 28 61 6 5 24 115 124 34 -1 4 25 161 106 20 2 3 26 0 43 1
-6 2 23 152 164 20 3 8 23 176 160 17 -5 6 24 0 41 1 0 4 25 67 67 59 3 3 26 91 80 40
-5 2 23 59 43 58 4 8 23 29 52 28 -4 6 24 57 53 57 1 4 25 81 88 39 4 3 26 106 62 31
-4 2 23 125 127 20 -3 9 23 0 32 1 -3 6 24 85 77 49 2 4 25 0 20 1 5 3 26 0 45 1
-3 2 23 112 79 23 -2 9 23 0 68 1 -2 6 24 0 63 1 3 4 25 165 147 23 6 3 26 246 245 20
-2 2 23 107 64 20 -1 9 23 78 111 61 -1 6 24 135 78 28 4 4 25 0 32 1 -5 4 26 100 89 31
-1 2 23 181 191 19 0 9 23 15 41 14 0 6 24 104 74 36 5 4 25 136 90 27 -4 4 26 95 11 27
0 2 23 274 290 17 1 9 23 107 97 30 1 6 24 118 76 28 6 4 25 61 85 60 -3 4 26 96 132 32
1 2 23 180 185 19 2 9 23 106 55 40 2 6 24 102 82 23 -5 5 25 47 42 47 -2 4 26 170 129 34
2 2 23 0 43 1 3 9 23 71 27 52 3 6 24 71 92 49 -4 5 25 208 172 19 -1 4 26 42 25 41
3 2 23 69 84 52 0 0 24 118 151 56 4 6 24 0 57 1 -3 5 25 41 38

41 0 4 26 71 34 48
4 2 23 155 127 26 1 0 24 162 139 14 5 6 24 73 33 46 -2 5 25 90 51 30 1 4 26 70 32 70
5 2 23 0 48 1 2 0 24 0 25 1 -5 7 24 52 15 52 -1 5 25 142 83 25 2 4 26 165 144 21
6 2 23 179 153 21 3 0 24 0 14 1 -4 7 24 37 28 36 0 5 25 68 6 67 3 4 26 123 122 27
7 2 23 64 83 63 4 0 24 135 111 20 -3 7 24 42 47 42 1 5 25 85 85 36 4 4 26 40 15 39
-7 3 23 137 121 24 5 0 24 0 59 1 -2 7 24 112 114 46 2 5 25 112 67 27 5 4 26 105 87 54
-6 3 23 0 17 1 6 0 24 76 54 43 -1 7 24 47 86 47 3 5 25 60 39 59 -5 5 26 83 72 39
-5 3 23 124 141 22 7 0 24 115 96 34 0 7 24 39 63 38 4 5 25 178 169 21 -4 5 26 100 76 30
-4 3 23 76 60 36 -7 1 24 146 132 22 1 7 24 102 72 33 5 5 25 75 31 74 -3 5 26 45 49 45
-3 3 23 63 47 46 -6 1 24 68 88 68 2 7 24 121 110 47 -5 6 25 75 71 66 -2 5 26 67 60 66
-2 3 23 62 27 43 -5 1 24 181 191 17 3 7 24 63 32 63 -4 6 25 165 140 41 -1 5 26 150 108 25
-1 3 23 90 102 28 -4 1 24 145 120 18 4 7 24 0 31 1 -3 6 25 0 72 1 0 5 26 0 69 1
0 3 23 54 79 54 -3 1 24 114 111 22 5 7 24 64 37 63 -2 6 25 214 168 21 1 5 26 125 99 25
1 3 23 87 71 26 -2 1 24 123 121 19 -3 8 24 88 45 44 -1 6 25 111 80 35 2 5 26 0 57 1
2 3 23 0 22 1 -1 1 24 85 62 30 -2 8 24 172 132 23 0 6 25 77 86 76 3 5 26 103 48 28
3 3 23 25 37 24 0 1 24 0 70 1 -1 8 24 155 129 34 1 6 25 77 69 47 4 5 26 68 68 67
4 3 23 56 50 56 1 1 24 46 64 45 0 8 24 88 65 34 2 6 25 171 168 20 5 5 26 129 97 26
5 3 23 157 151 22 2 1 24 134 134 17 1 8 24 139 125 25 3 6 25 104 63 23 -4 6 26 158 154 26
6 3 23 94 42 35 3 1 24 85 105 38 2 8 24 123 112 38 4 6 25 145 132 23 -3 6 26 57 79 56
7 3 23 113 111 33 4 1 24 126 109 21 3 8 24 43 50 43 5 6 25 116 71 23 -2 6 26 134 91 27
-7 4 23 124 105 27 5 1 24 171 182 17 -2 9 24 124 84 52 -4 7 25 50 103 50 -1 6 26 154 132 42
-6 4 23 66 86 66 6 1 24 54 69 53 -1 9 24 73 64 73 -3 7 25 137 88 26 0 6 26 227 218 39
-5 4 23 146 176 20 7 1 24 96 123 40 0 9 24 137 74 23 -2 7 25 115 124 34 1 6 26 168 129 20
-4 4 23 113 124 22 -7 2 24 119 85 26 1 9 24 161 78 21 -1 7 25 125

57 30 2 6 26 138 107 23
-3 4 23 105 87 23 -6 2 24 109 100 28 2 9 24 71 80 71 0 7 25 142 86 27 3 6 26 99 78 23
-2 4 23 153 145 15 -5 2 24 114 79 24 1 0 25 0 85 1 1 7 25 89 54 38 4 6 26 160 161 16
-1 4 23 61 33 61 -4 2 24 142 161 22 2 0 25 277 282 17 2 7 25 161 140 21 -3 7 26 109 72 108
0 4 23 37 40 36 -3 2 24 168 154 28 3 0 25 0 19 1 3 7 25 108 87 24 -2 7 26 0 67 1
1 4 23 85 53 38 -2 2 24 193 203 15 4 0 25 160 141 17 4 7 25 95 90 69 -1 7 26 133 68 28
2 4 23 133 144 32 -1 2 24 291 254 19 5 0 25 76 102 42 -3 8 25 264 254 46 0 7 26 99 44 43
3 4 23 109 91 28 0 2 24 398 406 14 6 0 25 165 148 20 -2 8 25 68 40 67 1 7 26 21 54 20
4 4 23 137 123 24 1 2 24 274 242 13 7 0 25 63 11 63 -1 8 25 163 134 26 2 7 26 58 69 58
5 4 23 148 167 24 2 2 24 201 211 14 -7 1 25 11 47 10 0 8 25 91 20 43 3 7 26 47 55 46
6 4 23 89 88 46 3 2 24 175 154 15 -6 1 25 92 88 33 1 8 25 167 148 21 -2 8 26 186 108 23
7 4 23 78 99 67 4 2 24 135 152 35 -5 1 25 211 190 16 2 8 25 63 43 62 -1 8 26 72 76 71
-6 5 23 88 91 54 5 2 24 64 93 64 -4 1 25 129 100 20 3 8 25 245 263 14 0 8 26 102 83 40
-5 5 23 106 86 27 6 2 24 110 105 32 -3 1 25 55 68 55 0 9 25 119 53 35 1 8 26 30 77 29
-4 5 23 151 135 17 7 2 24 66 81 65 -2 1 25 119 108 20 0 0 26 279 251 31 2 8 26 8 95 7
-3 5 23 241 222 14 -7 3 24 92 77 35 -1 1 25 260 217 20 1 0 26 172 165 25 1 0 27 77 104 76
-2 5 23 131 123 25 -6 3 24 166 154 20 0 1 25 316 283 20 2 0 26 120 124 21 2 0 27 100 45 32
-1 5 23 165 170 18 -5 3 24 281 268 15 1 1 25 230 212 18 3 0 26 126 114 21 3 0 27 173 185 16
0 5 23 111 6 24 -4 3 24 64 34 56 2 1 25 147 107 17 4 0 26 168 160 18 4 0 27 0 31 1
1 5 23 213 184 16 -3 3 24 182 152 16 3 1 25 97 70 39 5 0 26 107 66 33 5 0 27 70 43 55
2 5 23 140 134 16 -2 3 24 44 68 43 4 1 25 72 91 50 6 0 26 99 110 30 6 0 27 0 41 1
3 5 23 240 230 17 -1 3 24 185 182 23 5 1 25 164 195 22 -6 1 26 131 128 24 -6 1 27 61 16 61
4 5 23 149 137 24 0 3 24 458 495 22 6 1 25 146 115 25 -5 1 26 122 91 23 -5 1 27 0 20 1

Table 8. Observed and calculated structure factors for $C_{19}H_{19}BrNO_5S$
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h k l 10Fo 10Fc 10s h k l 10Fo 10Fc 10s h k l 10Fo 10Fc 10s h k l 10Fo 10Fc 10s h k l 10Fo 10Fc 10s

-4 1 27 0 77 1 -3 6 27 89 127 88 0 4 28 0 9 1 3 3 29 0 34 1 0 4 30 120 38 59
-3 1 27 95 49 37 -2 6 27 182 184 28 1 4 28 122 79 34 4 3 29 154 89 24 1 4 30 33 34 32
-2 1 27 42 61 42 -1 6 27 11 10 11 2 4 28 0 24 1 -4 4 29 91 69 43 2 4 30 110 66 36
-1 1 27 105 78 40 0 6 27 112 84 34 3 4 28 131 81 26 -3 4 29 214 173 23 3 4 30 129 89 28
0 1 27 0 33 1 1 6 27 22 15 21 4 4 28 113 77 29 -2 4 29 71 68 71 -2 5 30 94 43 94
1 1 27 85 75 35 2 6 27 184 187 20 -4 5 28 120 97 30 -1 4 29 117 102 34 -1 5 30 47 45 46
2 1 27 70 57 40 3 6 27 120 116 28 -3 5 28 145 104 29 0 4 29 89 72 44 0 5 30 104 22 38
3 1 27 40 45 39 4 6 27 0 32 1 -2 5 28 155 102 28 1 4 29 7 92 6 1 5 30 0 51 1
4 1 27 113 66 24 -2 7 27 113 52 38 -1 5 28 109 78 35 2 4 29 76 63 76 2 5 30 115 36 85
5 1 27 34 28 34 -1 7 27 81 56 63 0 5 28 85 43 48 3 4 29 218 177 32 1 0 31 272 200 23
6 1 27 0 29 1 0 7 27 0 59 1 1 5 28 173 87 26 4 4 29 110 67 38 2 0 31 100 64 45
-6 2 27 115 135 28 1 7 27 93 55 52 2 5 28 116 97 28 -3 5 29 83 26 82 3 0 31 68 20 67
-5 2 27 85 38 37 2 7 27 75 66 75 3 5 28 104 117 39 -2 5 29 0 83 1 -3 1 31 200 139 25
-4 2 27 59 26 58 0 0 28 405 408 30 4 5 28 115 87 40 -1 5 29 118 53 57 -2 1 31 122 92 122
-3 2 27 30 67 30 1 0 28 71 36 70 -3 6 28 73 22 72 0 5 29 80 99 79 -1 1 31 207 157 24
-2 2 27 20 71 19 2 0 28 127 140 24 -2 6 28 101 26 100 1 5 29 98 59 50 0 1 31 154 112 29
-1 2 27 204 180 22 3 0 28 101 47 25 -1 6 28 141 104 26 2 5 29 0 69 1 1 1 31 184 156 49
0 2 27 174 176 24 4 0 28 93 14 28 0 6 28 154 185 26 3 5 29 0 36 1 2 1 31 127 93 33
1 2 27 201 192 18 5 0 28 94 27 37 1 6 28 110 102 39 -2 6 29 165 130 44 3 1 31 162 144 22
2 2 27 60 77 60 -5 1 28 75 128 51 2 6 28 108 38 31 -1 6 29 112

68 35 -3 2 31 76 38 76
3 2 27 71 74 44 -4 1 28 90 128 33 3 6 28 0 20 1 0 6 29 83 73 83 -2 2 31 118 67 38
4 2 27 0 30 1 -3 1 28 163 147 18 -1 7 28 63 85 63 1 6 29 113 55 49 -1 2 31 63 63 62
5 2 27 97 30 35 -2 1 28 78 60 77 0 7 28 107 3 40 2 6 29 160 133 21 0 2 31 140 92 32
6 2 27 154 127 24 -1 1 28 139 86 28 1 7 28 139 95 30 0 0 30 125 65 51 1 2 31 104 56 45
-5 3 27 59 42 58 0 1 28 40 69 40 1 0 29 183 188 26 1 0 30 0 4 1 2 2 31 89 63 36
-4 3 27 287 269 23 1 1 28 121 78 58 2 0 29 192 156 24 2 0 30 34 47 34 3 2 31 67 37 67
-3 3 27 63 44 62 2 1 28 131 66 23 3 0 29 0 31 1 3 0 30 115 133 28 -2 3 31 120 45 35
-2 3 27 215 225 23 3 1 28 156 134 19 4 0 29 135 70 22 4 0 30 74 4 43 -1 3 31 133 132 133
-1 3 27 90 70 43 4 1 28 159 128 19 5 0 29 66 59 66 -4 1 30 167 127 19 0 3 31 0 33 1
0 3 27 69 43 69 5 1 28 111 131 33 -5 1 29 0 7 1 -3 1 30 105 71 43 1 3 31 156 140 52
1 3 27 107 70 27 -5 2 28 128 110 24 -4 1 29 89 14 33 -2 1 30 95 82 56 2 3 31 97 51 97
2 3 27 263 231 18 -4 2 28 36 33 36 -3 1 29 0 48 1 -1 1 30 48 83 47 -2 4 31 0 41 1
3 3 27 98 52 36 -3 2 28 111 104 28 -2 1 29 143 94 28 0 1 30 352 342 31 -1 4 31 0 43 1
4 3 27 252 260 18 -2 2 28 70 38 70 -1 1 29 216 218 22 1 1 30 68 78 68 0 4 31 75 31 75
5 3 27 0 49 1 -1 2 28 79 105 67 0 1 29 160 128 27 2 1 30 66 82 65 1 4 31 0 45 1
-5 4 27 125 98 30 0 2 28 0 34 1 1 1 29 225 215 22 3 1 30 111 61 31 2 4 31 118 39 38
-4 4 27 67 46 67 1 2 28 141 110 32 2 1 29 77 105 54 4 1 30 116 120 30 0 0 32 208 228 35
-3 4 27 69 90 68 2 2 28 32 37 31 3 1 29 58 39 58 -4 2 30 149 96 24 1 0 32 136 101 32
-2 4 27 115 66 32 3 2 28 23 104 22 4 1 29 83 31 36 -3 2 30 119 69 33 2 0 32 0 67 1
-1 4 27 143 155 20 4 2 28 73 38 72 5 1 29 138 12 24 -2 2 30 169 126 30 -2 1 32 0 57 1
0 4 27 117 114 32 5 2 28 101 115 39 -4 2 29 121 95 22 -1 2 30 130 100 30 -1 1 32 155 93 29
1 4 27 159 143 26 -5 3 28 88 6 33 -3 2 29 0 62 1 0 2 30 82 30 77 0 1 32 0 12 1
2 4 27 56 70 56 -4 3 28 77 54 38 -2 2 29 144 135 42 1 2 30 117

103 34 1 1 32 153 93 29
3 4 27 74 97 74 -3 3 28 109 109 30 -1 2 29 0 50 1 2 2 30 132 132 25 2 1 32 100 51 82
4 4 27 67 45 66 -2 3 28 126 83 46 0 2 29 64 34 63 3 2 30 24 74 24 -2 2 32 96 26 54
5 4 27 115 101 32 -1 3 28 101 56 41 1 2 29 38 50 38 4 2 30 120 93 61 -1 2 32 34 59 33
-4 5 27 132 127 26 0 3 28 69 16 57 2 2 29 160 134 21 -3 3 30 33 65 33 0 2 32 0 74 1
-3 5 27 121 119 32 1 3 28 0 49 1 3 2 29 105 63 31 -2 3 30 23 137 22 1 2 32 0 59 1
-2 5 27 71 77 71 2 3 28 84 84 43 4 2 29 144 90 26 -1 3 30 0 18 1 2 2 32 0 24 1
-1 5 27 25 69 25 3 3 28 142 119 24 -4 3 29 144 104 24 0 3 30 188 167 23 -1 3 32 83 65 56
0 5 27 0 43 1 4 3 28 67 52 66 -3 3 29 113 37 38 1 3 30 69 19 68 0 3 32 129 98 39
1 5 27 106 67 39 5 3 28 21 13 20 -2 3 29 68 108 67 2 3 30 129 129 35 1 3 32 138 68 51
2 5 27 130 79 35 -4 4 28 62 81 62 -1 3 29 155 85 59 3 3 30 94 69 39 0 1 33 143 33 32
3 5 27 127 126 20 -3 4 28 147 78 30 0 3 29 99 28 36 -3 4 30 120 93 119
4 5 27 138 109 42 -2 4 28 70 35 70 1 3 29 84 84 36 -2 4 30 0 69 1
-4 6 27 100 35 41 -1 4 28 167 80 41 2 3 29 116 100 34 -1 4 30 0 32 1